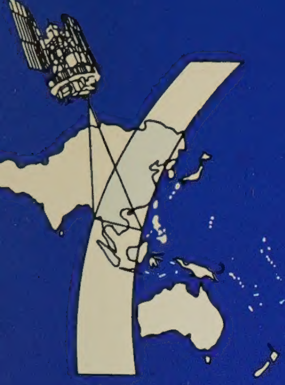
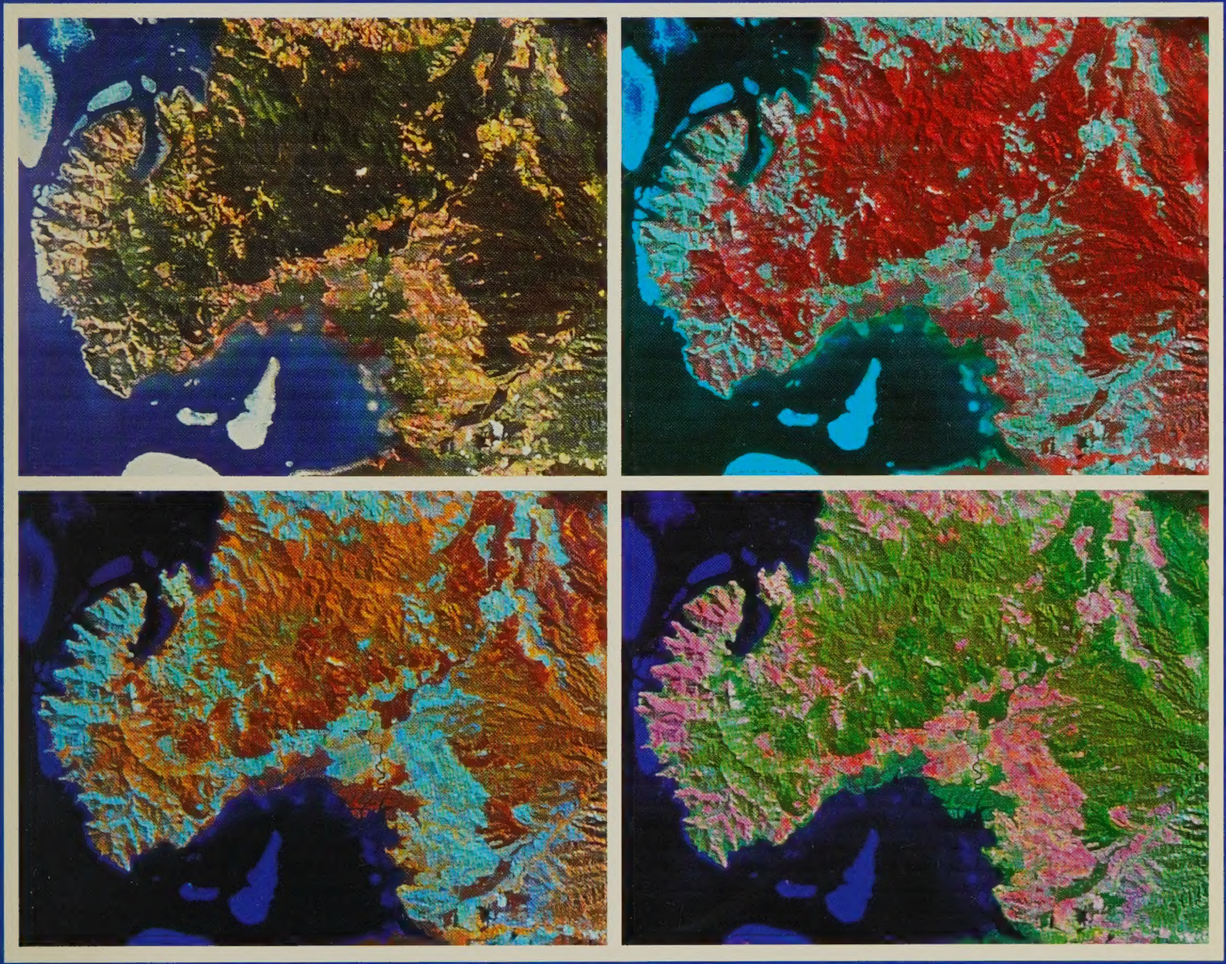


REMOTE SENSING AND GIS FOR LAND AND MARINE RESOURCES AND ENVIRONMENT MANAGEMENT

Proceedings of the Regional Workshop on Remote Sensing and GIS for Land and Marine Resources and Environment Management in the Pacific Subregion



Jointly organized by
the Ministry of Lands, Mineral Resources and Energy, Government of Fiji
the South Pacific Regional Environment Programme, and the
Economic and Social Commission for Asia and the Pacific

Suva, Fiji

13-17 February 1995

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PART ONE
REPORT OF THE WORKSHOP

REPORT OF THE REGIONAL WORKSHOP ON REMOTE SENSING/GIS FOR LAND AND MARINE RESOURCES AND ENVIRONMENT MANAGEMENT IN THE PACIFIC SUBREGION

A. Organization of the Workshop

1. The Remote Sensing/GIS Workshop for Land and Marine Resources and Environment Management in the Pacific Subregion was held in Suva, Fiji from 13 to 17 February 1995. The workshop was organized by the Economic and Social Commission for Asia and the Pacific (ESCAP) in close collaboration with the Government of Fiji, through the Ministry of Lands, Mineral Resources and Energy, and the South Pacific Regional Environment Programme (SPREP).

2. The workshop had two main objectives: the first was to expose senior officials from departments utilizing remote sensing and/or GIS for land and marine resources and environment management to the new technology developments through an exchange of information on the status of development and a series of lectures on the latest GIS and remote sensing applications. The second objective was to formulate a subregional action plan in remote sensing and GIS applications for development as a follow-up to the Ministerial Conference on Space Applications for Development in Asia and the Pacific held in September 1994.

Attendance

3. The Workshop was attended by 72 participants from 18 countries: Australia, Canada, the Cook Islands, the Federated States of Micronesia, Fiji, France, French Polynesia, Guam, Kiribati, the Marshall Islands, New Caledonia, New Zealand, Niue, Palau, Solomon Islands, Tonga Tuvalu and Vanuatu; 9 from regional organizations and other agencies: Forum Fisheries Agency, the International Board for Soil Research and Management (IBSRAM), South Pacific Applied Geoscience Commission, South Pacific Commission, South Pacific Regional Environment Programme and the University of South Pacific; and 8 from the United Nations system including, the United Nations Environment Programme (UNEP) and the United Nations Development Programme (UNDP).

Opening of the Workshop

4. The Workshop was inaugurated by the Honourable Ratu Timoci Vesikula, Minister for Lands, Mineral Resources and Energy of Fiji. In his address, he mentioned that socio-economic development was closely tied to sustainable use of resources and their impact on the environment. There was a growing realization that socio-economic development could be sustainable only if resources were exploited in a judicious manner. He also said that the common problems for many Pacific islands States were limited natural resources and a substantial lack of technical expertise. Population growth increased pressure on land and resources and new resources had to be exploited to provide decent living standards. Geographic information systems were versatile and promising tools that could be gainfully employed in conjunction with satellite-based data for optimizing resource and environmental management.

5. In his welcome address, Mr Bhuwan Dutt, the Permanent Secretary for Lands, Mineral Resources and Energy reminded the audience that through the regional remote sensing programme ESCAP had given an impetus to remote sensing activities in the region by the holding of a number of activities such as the current workshop. The Permanent Secretary was pleased to see that it had been organized shortly after the Ministerial Conference on Space Applications for Development in Asia and the Pacific held in September 1994, in Beijing.

6. In his address of welcome, the UNDP Resident Representative highly praised the success and impact of the regional remote sensing programme on the Pacific subregion. He appreciated that the participants had come together as a group from the South Pacific to discuss the applications of remote sensing/GIS for planners and decision makers. Meeting as a regional group provided room for the sharing of a wealth of experience in the field and allowed for a first hand discussion of the successes and failures of different stages in the implementation of GIS/remote sensing programmes that were complex and ambitious, both in their technology and policy applications. The pooling of expertise, efforts and, in some instances, finances in the GIS/remote sensing sector seemed to make a lot of sense in providing a more viable and sustainable basis upon which to build new endeavours in that fast changing field.

7. On behalf of the ESCAP secretariat, the Officer-in-Charge of the Space Technoloby Applications Section, Environment and Natural Resources Management Division, made a statement. The activities that had been held in the Pacific subregion since the beginning of the regional remote sensing programme and especially over the last 5 years were outlined. The developments in the field by the individual Pacific island countries and by regional organizations that had occurred were highly encouraging. However, he noted, despite those efforts, enhanced cooperation had yet to be developed in order to meet the growing development requirements of those countries in that field of technology. ESCAP strongly believed that by working closely alongside SPOCC and its associated agencies, important strides would be made towards improving the capabilities of the individual countries in the region in the efficient use of GIS and remote sensing for natural resources and environmental management.

Election of Officers

8. Mr Bhuwan Dutt, Permanent Secretary for Lands, Mineral Resources and Energy, was elected Chairperson, Mr Oliver Peyroux, Chief Surveyor, Cook Islands, was elected Vice-Chairperson and Mr Martin Sokomanu, Senior Hydrographic and Computer Management Officer, Vanuatu, was elected Rapporteur.

B. Workshop proceedings

1. Country presentations

9. Presentations were made by 15 countries on the current activities being carried out in the applications of GIS/remote sensing in the Pacific subregion to address natural resources and environmental management issues.

The Cook Islands

10. After the destruction of the majority of maps and digial map data because of a fire in the early 1990s, an ambitious GIS project was initiated in the Cook Islands in cooperation with the Government of New Zealand. The project involved the Department of Survey which was the Executing Agency, as well as the Ministry of Agriculture and Forestry, the Ministry of Works and the Conservation Service of the Cook Islands. An important component of the project was the development of a protocol for sharing data and resources which was being finalized. Training of GIS operators, in particular for the construction of the database which included cadastral plans, topographic maps and soils maps, was carried out and completed by the end of 1993.

French Polynesia

11. French Polynesia was currenctly using two operational geographic information systems: one for lagoon pearl culture management and another for urban applications. Other applications of interest to the country included land-use planning, coastal zone management, lagoon studies, natural resources management, forest resources monitoring, isolated islands mapping and monitoring as well as the design of educational programmes at the high school level. The Polynesian Station of Remote Sensing was one of the main bodies providing remote sensing/GIS services to the user community. It was a partnership

between IFREMER, a French Research Institute, and French Polynesia and it had become a centre of excellence for remote sensing/GIS activities.

Federated States of Micronesia

12. The Federated States of Micronesia Office of Planning and Statistics was the designted agency for GIS operations for the national Government. The office would be acquiring two systems and would eventually house the GIS division for Government. A geographic information system was acquired in the Pohnpei State Division of Forestry under a joint watershed project funded by the Asian Development Bank (ADB) but its use remained limited owing to a lack of personnel training.

Fiji

13. A number of governmental agencies were involved in remote sensing/GIS activities in Fiji including the Department of Lands and Surveys which established the Fiji Land Information System, the Native Land Trust Board, the Department of Environment, the Department of Forestry, the Mineral Resources Department, the Department of Meteorology, and the Department of Agriculture. Such a large number of governmental agencies, in addition to the statutory organizations based in Fiji that were also involved in GIS activities, had sparked the creation of the Fiji Land Information Council, a structure aiming to ensure a coordinated approach to the development of a national information system. Its main functions were the development and coordination of all GIS projects as well as funding, policy formulation, training and education, management and direction of the Fiji Land Information Systems (FLIS) support centre which was established to manage the Council's decisions.

Guam

14. The Government of Guam had been involved with GIS development for the past several years. The Bureau of Planning had produced parcel-base maps with assistance from the Department of Land Management and private consultants. A GIS user group had been set up to represent all government agencies. It was responsible for networking gevernment agencies using GIS technology as well as stting up data standards and data exchange procedures. Other GIS activities included the digitization of thematic and infrastructure maps. GPS activities were also being carried out, in particular to re-establish the geodetic network and provide more accurate positioning of infrastructure facilities.

Kiribati

15. Remote sensing/GIS technologies had only recently been introduced in Kiribati. Maplnfo had been installed and software updates had been received under the SOPAC programme. On-the-job training had been provided to two nationals on the use of that software. However, the construction of a digital map base for the country had not been possible because of a lack of funds necessary for the acquisition of a digitizer. The workshop had provided a good opportunity for the participant to learn more about the technology and to share experiences with participants from other Pacific islands countries.

New Caledonia

16. A partnership between the Service des Methodes Administratives et de l' Informatique (SMAI) and ORSTOM was established in 1992 to conduct remote sensing activities which, more recently, led to involvement in GIS activities. An overview of last year's remote sensing projects was presented including examples of natural hazards impact studies and land management: the volcanic eruption of Rabaul (Papua New Guinea) and its impact on land use as well as the nickel mining mapping project for environmental rehabilitation purposes. Examples of existing GIS projects were given in urban applications (GIE Serail project for the city of Noumea), in customary land property studies in the Loyalty Island Province as well as the ZONECO marine GIS programme used to manage the New Caledonian Executive Economic Zone (EEZ). The main projects for 1995 included the construction of a territorial scale GIS for the concerned governmental departments, on the basis of topographic and cadastral information;

the establishment of a new NOAA reception station for scientific uses, co-financed by ORSTOM and the French Territory; and the acquisition of a set of 50 SPOT archive images on South Pacific countries, excluding New Caledonia, in order to complete ORSTOM's collection.

Niue

17. Remote sensing was not currently used in Niue but its great potential had been recognized for the management of forest and marine resources. A MAPINFO geographic information system had been installed but was not being used to its maximum potential owing to limited training. The principal applications of interest in the country were land ownership and related activities, bore site mapping and soils mapping. The following information layers to be contained in the national database included forest resources, land available for leases, conservation areas and public utilities. Applications of high interest included disaster monitoring and mitigation and environmental management and monitoring.

Palau

18. The most ambitious GIS project in the country was the Palau Integrated Land Information and Geographic Information System. It was at the stage of technical and organizational consideration and two companies, from Australia and Japan, had submitted their proposals to the Government of Palau. The project would play an important role in strengthening the environmental management regulatory framework and would require both financial and technical assistance from donor countries and agencies. The National Master Development Plan, currently under development, was geared towards economic development prospects with great emphasis placed on tourism, agriculture and fisheries. The integrated LIS/GIS was to provide the basic land information to support the decision-making process associated with the Master Plan and related to land utilization control, land development control, environmental development control, facility operations control and disaster prevention/security control.

Solomon Islands

19. One of the most important remote sensing applications in the Solomon Islands consisted in geological appraisal/mapping. The problems of accessibility of the islands owing to their rugged terrain and thick rain forest cover made remote sensing a particularly interesting alternative for mapping the country's natural resources. However, at present, lack of equipment and personnel with the necessary skills resulted in limited use of the technology. The Government of the Solomon Islands welcomed any regional cooperation activity from which it could benefit by the sharing of experience.

Tonga

20. The Ministry of Lands, Survey and Natural Resources has installed the MAPINFO software on its system but it was not currently being used because of a lack of trained personnel.

Tuvalu

21. Remote sensing was not currently used in Tuvalu but GIS technology had recently been introduced through the installation of MAPINFO under the SOPAC programme. The workshop was appreciated by the participant as a good opportunity to learn more about the technology and its potential application to the country.

Vanuatu

22. The Department of Lands and Surveys, responsible for surveying and mapping of the country, owned a Land Information System that was currently being used by the Department of Land Records. Recent additions to the system include Microstation software for which a training course was under way. Another available system was the Vanuatu Resource Information System (VANRIS), designed to provide an operational planning tool to assist land-use planners and resources agencies for natural resource management

purposes. Based on a system consisting of a database management system (FOXPRO) and a desktop mapping software (MAPINFO), it contained a large and comprehensive inventory of the nation's natural resources, land use and population distribution and was installed in all the major agencies concerned with natural resources planning and management, including the Departments of Forestry, Agriculture, Land Surveys, Environment, and the National Planning and Statistical Office, as well as by local governments.

2. Presentations from regional organizations

23. Presentations were also made by a number of regional organizations of the South Pacific.

South Pacific Applied Geoscience Commission (SOPAC)

24. SOPAC was a regional intergovernmental organization whose mandate was to assist its member countries in managing, in a sustainable way, their non-living resources. That implied collecting, storing and analyzing, as well as distributing data and information. The data, numerous and varied, were related to offshore areas, coastal areas and onshore areas. SOPAC had produced maps for the member countries for a long time but was progressively transferring that capacity to the member countries.

25. SOPAC had acquired quite comprehensive GIS/remote sensing facilities and had become a centre of excellence in the field of remote sensing and GIS applications, particularly with respect to coastal zone geology and deep water morphology.

South Pacific Commission (SPC)

26. The South Pacific Commission was a regional organization subscribed to and controlled by the Governments of Australia, American Samoa, the Cook Islands, the Federated States of Micronesia, Fiji, France, French Polynesia, Guam, Kiribati, the Marshall Islands, New Caledonia, New Zealand, Niue Northern Mariana Islands, Papua New Guinea, Palau, the Solomon Islands, Tokelau, Tonga, Tuvalu, the United Kingdom of Great Britain and Northern Ireland, the United States of America, Vanuatu, Wallis and Futuna, and Samoa. SPC provided development and advisory services to the Pacific islands with programmes in several areas including the fisheries programme. That particular programme had the greatest current interest in using remote sensing and spatial information systems in its work to enhance existing services in fisheries management to member countries. SPC had signed a Memorandum of Understanding with other South Pacific regional organizations the Forum Fisheries Agency (FFA), SOPAC, SPREP and the University of the South Pacific (USP) to facilitate the sharing of remote sensing data and avoidance of duplication of effort, through the South Pacific Organizations Coordinating Committee (SPOCC). SPC made considerable use of spatially referenced data in the assessment and monitoring of tuna fisheries, including several types of cartographic interface.

South Pacific Regional Environment Programme (SPREP)

27. The UNEP Environment Assessment Programme for Asia and the Pacific established, through SPREP, the Pacific Environment and Natural Resource Information Center (PENRIC) to cater to the environment information needs of the member countries of the South Pacific for sustainable planning and environmentally sound decision-making.

28. The core of PENRIC was to assess existing environmental data and determine their status in terms of format and availability. Remote sensing data were incorporated in GIS, thereby integrating layers of information that could be used for sustainable planning and development. Emphasis was also placed on national capacity-building through training, institution building and provisions for hardware and software where appropriate.

29. SPREP was mandated to take the coordinating role in environmental issues for the South Pacific region. The thrust of its action plan was determined by the projects within the programme in collaboration with the national environment management strategies developed for its member countries.

University of South Pacific (USP)

30. To meet an increasing demand for GIS/RS involvement and human resources development in its region, the University of South Pacific established the USP GIS unit in 1994 to provide training, education and services. A teaching lab and associated facilities were constructed with the assistance of UNEP and faculty allocated to the unit. Currently, an Introduction to GIS course (Geography 204) has been offered and others were planned. There were requests for GIS/RS professional certification and a diploma programme was under development, including workshops and short courses. Outreach services, such as GIS distance training, were also under planning. With the collaboration of the user community, a programme of human resources development was to be undertaken to offer a variety of training, education, and assistance services.

3. Lectures

31. Lectures were presented by a number of resource persons with condiderable experience in remote sensing and GIS applications in the Pacific environment.

Session 1: General introduction to GIS and remote sensing

32. Professor Barry Garner of the University of New South Wales of Australia made an introduction to the topic of GIS and remote sensing. In his presentation, some of the key problems in changing from traditional ways of storing geographical data to computerized systems were highlighted. The advantages and value of digital geo-referenced data for environmental applications were discussed along with the potential for cost savings within organizations through data sharing and by avoiding duplication of effort and redundancy of resources. The need to design spatial information systems to cater adequately to the needs of the three different levels of users (operation, management and policy-making) in any organization was also emphasized.

33. Remote sensing, GIS and spatial information technologies were rapidly developing in capability to address environmental problems, but in many respects they were still in their infancy. Current trends and future directions in the development of those technologies included the shift in emphasis from applications dealing with natural resources to those focusing on human resources. As a result, databases were becoming increasingly diversified in content, an important, if not essential, consideration for GIS applications related to sustainable development. Professor Garner also highlighted other developments which included the incorporation of mathematical modelling capability, essential if GIS was to help answer questions of the What if? rather than those of the What or Where kind, and the integration of GIS with communications media to produce multi-media systems and more sophisticated display capabilities to enable visualization of 3-D and 4-D data as well as spatial dynamics analysis.

Session 2: Introduction to remote sensing applications

34. Mr Peter Stephens, team leader of Landcare Research of New Zealand, presented an introductory lecture on remote sensing applications illustrated with examples of some of the common applications in the Pacific region. He described the four important qualities of remotely-sensed images relevant to natural resources management: the objectivity, quantitative nature and permanence of the data as well as the ease with which it could be manipulated by computers and integrated with other spatial (GIS) data sets.

35. Mr Stephens emphasized that the use of remotely sensed data by appropriately trained and equipped staff allowed agencies involved in natural resources management to obtain inventories of natural resources, to monitor changes occurring to relevant natural resources, to assist in site selection for specific studies and to assist in determining the relationship between land management and land degradation and/or sustainable land-use practices.

Session 3: Remote sensing applications for land and marine resources and environment management

36. Mr Yann Morel, Head of the Polynesian Remote Sensing Facility, Tahiti, presented examples of the use of geographic information derived from remotely sensed data in the French Polynesia context. A database of SPOT satellite images had been used since 1988 by the Territory of French Polynesia in cooperation with IFREMER to derive various base map products at the 1:50,000 scale in atoll environments. Those products ranged from simply enhanced image map hardcopies (UTM, WGS84) to a digital base map in the form of contours extracted by thresholding methods for use in GIS applications. In addition, a protocol for computer-aided photo interpretation had been worked out through a cooperative research project involving the French University of the Pacific and the Topographic Section of the Town Planning Service. That protocol provided a set of professional rules that would be used for the production of an accepted temporary substitute to the standard topographic map, in digital form and for several tens of atolls. Those rules should also later cover the subsequent production of a fully auto-calibrated bathymetric model (0 to 15-25 m) and of a normalized image map of the lagoon bottom reflectance down to 3 to 6 m.

37. In his second lecture, Mr Stephens pointed out that application projects had demonstrated the considerable potential of remotely sensed data for land resources management. Worldwide, and more particularly in the South Pacific, there were few operational uses of remotely sensed data for natural resources management and environmental monitoring.

38. The key to making remote sensing operational for natural resources management would not be the use of a single sensor to solve all issues, but the integration of data from a range of sensors with other geographic and socio-economic information. That would only occur when there was a mature service sector within the South Pacific to provide help, guidance, and data to potential users who had problems requiring the use of remotely sensed data and spatial information systems. The suppliers of remotely sensed data should relieve users of heavy pre-processing workloads, and make the data more suitable for use by the Pacific user community. Data should be made generally available as products that are easily integrated with other data sets and GIS.

39. The South Pacific user community was generally unaware of the potential of remote sensing and spatial information systems. When resource managers within the South Pacific become familiar with remote sensing and spatial information systems, the gap between the potential use of remote sensing and its actual use would be reduced. With accompanying growth in the use of remotely-sensed data for resource management, users' confidence in its value would be enhanced. Only then would the benefits of remote sensing be realized for resource management and environmental monitoring activities in the South Pacific region.

Session 4: Introduction to GIS

40. Dr Qiming Zhou, senior lecturer of the University of New South Wales of Australia gave an introductory lecture on geographic information systems. He pointed out that GIS was a particular form of information system applied to geographic data and that GIS used geo-referenced data as well as non-spatial data and included operations which supported analysis and modelling. A complete GIS contained three major components: computer hardware, GIS software modules and organization aspects. In a typical GIS implementation, there should be the following technical and organizational considerations including: hardware, software, GIS personnel, data requirements, and data source and quality.

41. Most commonly used GIS data analysis and modelling capabilities included data query and display topological overlay, buffering and digital terrain models. To solve complicated problems, cartographic modelling techniques were often employed by combining a number of simple operators to implement a complex model. Dr Zhou spelled out a number of advantages for introducing GIS to planning. He pointed out that it was important to understand that GIS was of its maximum value when being used as a decision support tool rather than as a simple mapping or database system.

Session 5: GIS applications to land and marine resources environment management

42. In addressing the application of GIS to environmental management and monitoring, Professor Garner pointed out that many organizations simply used GIS as a database management tool and for the production of maps but did not exploit to the fullest extent its analytical capabilities to solve problems. Although querying databases to answer simple questions was useful and important as a starting point, it was the cartographic modelling capabilities of GIS that were significant in the applications context.

43. To demonstrate that, he presented a series of examples which were used to illustrate the concept of cartographic modelling and its implementation. He stressed that the successful use of GIS not only required an understanding of the technology itself but, more importantly, the specialist knowledge of a particular branch of environmental science.

44. Through the examples used, Professor Garner also pointed out that current technology was still in its infancy from many points of view, which prevented its full application to many types of environmental problems — particularly in process studies. That resulted from the fact that the current GIS lacked powerful mathematical modelling capabilities.

45. In addition, GIS did not handle temporal data adequately for many types of applications, in particular those relating to the study of the marine environment. It was, therefore, important that users were as familiar with the capabilities of GIS as well as its shortcomings when addressing problems of environmental management and monitoring of successful applications.

Session 6: GIS and remote sensing integration for land and marine resources and environment management

46. Addressing the integration of GIS and remote sensing, Dr Zhou argued that GIS and remote sensing integration represented a significant trend in Spatial Information Technology. The concept of integrated GIS had been developed which addressed both system integration and task-oriented integrations. Although significant progress had been reported in the past years, the evolution of integrated systems was still far away from satisfactory. However, current applications have shown that task-oriented integration was achievable and cost effective.

47. Through the case study of the Tweed River Region of North New South Wales, Australia, the environment modelling techniques had been demonstrated as an approach of task-oriented integration. In the regional planning case study, environment models such as land capability, land suitability and optimal highway route had been developed.

48. GIS, when integrated with remote sensing, made it possible for a real-time resource and environment management systems. Remotely sensed data, he observed, become much more useful when integrated into decision support procedures with GIS.

49. On that topic, Mr Yann Morel presented some experiences in integrating remote sensing with GIS, using examples from French Polynesia. Using digital base maps derived by simple thresholding methods from satellite images for 27 atolls, a GIS application was developed for the administrative and technical management of the pearl farming industry in French Polynesia. The data consisted of information elements contained in marine lease applications and granted leases and, most importantly, of the actual use being made of lagoon space by various activities. That allowed the processing of thousands of lease application dossiers, six times faster in a timely and efficient manner, and the handling and use of a very large amount of data collected on a regular basis by field control teams. After four years, the improvement in efficiency resulted in a twofold expansion of the yearly value of pearl exports.

50. The following phase would consist in replacing the existing digital base maps by true topographic base maps derived from satellite images, locally supplemented by topographic features extracted from aerial photographs for the most densely farmed areas.

4. Working groups on the subregional action plan

51. In pursuance of the Beijing Declaration on Space Technology Applications for Environmentally Sound and Sustainable Development in Asia and the Pacific, a working group was organized to formulate a subregional action plan for implementation under the action plan on space applications for sustainable development in Asia and the Pacific which was launched by the Ministerial Conference.

52. To that end, the participants were divided into three subgroups to develop project formulation frameworks under three different theme areas: capacity-building, data and information services, and technology applications. Subsequently, a portfolio of eight projects was developed, containing the following:

(a) Establishment of a sustained training/educational programme to provide initial and ongoing specialized and general training and support;

(b) Development of practical means and structures of communication within the Pacific region to foster the building of PIC GIS capacity;

(c) Mapping, inventory and analysis of marine resources in the "nearshore" zone;

(d) Mapping, inventory and analysis of land resources in coastal areas;

(e) Mapping, inventory, analysis and assessments for hazard mitigation in the coastal zone;

(f) Development of a regional dictionary of GIS/RS data at national and regional levels and a South Pacific information service network;

(g) Establishment of a mobile low-cost satellite ground receiving station in the Pacific subregion;

(h) Extraction of sea surface temperature from low resolution orbiting satellites.

53. These project profiles were presented and discussed during a panel session. The workshop agreed that the ESCAP secretariat should present the project portfolio to donors for early implementation.

5. Conclusions and recommendations

54. The Workshop emphasized that remote sensing and GIS were important, proven and efficient tools for addressing informaiton needs for natural resource and environmental management in the Pacific region. It recommended such technology applications and their integration with the national development activities should be vigorously promoted in the Pacific subregion.

55. The Workshop acknowledged with appreciation of ESCAP and UNDP the promotional efforts in the subregion through the Regional Remote Sensing Programme (RRSP). Such efforts, along with the activities initiated by the concerned subregional organizations, had enabled the subregion to increasingly benefit from the technology applications to natural resources and environment management sectors.

56. In the Pacific islands environment, airborne remote sensing, in particular aerial photography, was still an important tool for acquiring data for natural resources inventory and environment assessment.

57. Satellite remote sensing which could provide timely, comprehensive and accurate data, was becoming an important tool for the Pacific countries for implementation of sustainable development programmes such as Agenda 21.

58. High resolution satellite data such as SPOT and Landsat TM images used in combination with aerial photography could produce quality information required for disaster management such as cyclone damage mapping and assessment in small islands countries.

59. GIS was a powerful tool for handling spatial and attribute data for planners and decision makers. Customized GIS technology suitable for the environment of South Pacific countries should be given high priority.

60. The integration of remote sensing and GIS was an important new trend in technology development. Such integration not only provided greater possibilities for updating spatial data/information bases but also enabled timely and dynamic decision-making.

61. One major barrier to the operational use of remote sensing in the Pacific region was the lack of satellite remote sensing data. It was recommended that actions should be collectively taken by the subregional countries to acquire the capability of satellite data reception through the development of mobile ground receiving station, as envisaged in the action plan endorsed by the the Ministerial Conference.

62. High resolution meteorological satellite data used for environmental monitoring purposes had demonstrated great advantages for its near real-time accessibility, low cost and high-frequency coverage. It was, therefore, recommended that receiving stations capable of acquiring NOAA AVHRR data should be established wherever possible to provide information for environmental monitoring and particularly marine environment monitoring.

63. Cloud cover presented a serious problem in data accessibility in the subregion. Therefore, in the long run, the region should be prepared to use microwave remote sensing data which were already available from a number of satellite systems such as ERS-1, JERS-1 and soon, RADARSAT.

64. Consequently, it was recommended that the Pacific countries interested in microwave remote sensing contact RADARSAT International (RSI) for possible arrangements to obtain free RADARSAT images for conducting pilot research studies in selected areas of natural resources management in the subregion. The workshop further recommended that ESCAP should approach CCRS/RSI for arranging a joint training workshop on RADARSAT data utilization in the Pacific region.

65. The operational use of remote sensing and GIS depended upon the knowledge, skills, and experience of applications specialists in various fields of natural resources management. There was in general a serious lack of trained specialists in the field in the Pacific member countries. Therefore, training and education of remote sensing/GIS specialists should be given high priority and sustainable programmes in training and education sould be developed by the member countries.

66. To assist developing countries in the Pacific region, the existing GIS unit in the University of South Pacific, and subsequently other educational institutes in the South Pacific, should be strengthened by providing additional staff resources. A sustained programme, specially tailored to the characteristics of Pacific island countries, should be developed to provide advanced-level courses (at least up to the Masters degree level).

67. The acceptance of new technology such as remote sensing/GIS and their integration also very much depended on the understanding of planners and decision makers about the merits and applications of the technology. Therefore, promotional efforts to expose high-level planners and decision makers to the latest technology developments and experience on practical applications should be organized.

68. The knowledge and skills required for operating various remote sensing/GIS systems were an important component in the successful implementation of any remote sensing/GIS project. Therefore, the customized training of technical staff should be considered as an important project component in development aid programmes.

69. Introductory courses on remote sensing/GIS should be introduced in high schools to raise the awareness/interest of the younger generation on basic remote sensing/GIS technology. In that connection,

training materials, such as slides, videos, and booklets containing illustrations of relevant applications in the region, should be prepared.

70. It was quite often observed that, when new technology was introduced in an organization, it was met with a feeling of resistance by people used to more traditional techniques. To reduce such fears, efforts should be made to organize appropriate reorientation or re-training of the concerned personnel in the concerned agencies.

71. The successful introduction of remote sensing/GIS into national natural resources management programmes required the necessary infrastructure or, at least, institutional restructuring. In that connection, the establishment of a land information council by the Government of Fiji, for the overall coordination and collaboration among various governmental agencies, was recognized as a highly successful model for GIS/remote sensing technology adoption and adaptation in developing countries. It was recommended that such a mechanism be studied and emulated by other countries of the regions as appropriate.

72. At the regional level, the initiative of establishing a GIS/remote sensing memorandum of understanding to enhance inter-agency cooperation and coordination among SPOCC organizations was a welcome development. To assist those agencies in formulating a productive programme of cooperative actions, it was recommended that a study be conducted with the assistance of UNEP.

73. The sharing of information among different agencies and between different countries on existing remote sensing/GIS setups, on the status of remote sensing/GIS development and its applications, on national programmes and projects, as well as on technical personnel involved in remote sensing/GIS, was considered highly beneficial for all parties concerned. Related regional organizations were encouraged to establish and update, as required, such an information database.

74. To promote data sharing among various government agencies, the availability of remote sensing data should be recorded in a designated agency. That agency should be mandated to keep continuous track of any new data and make that information available to all government agencies.

75. The special resources inventory and communications needs of the Pacific island countries, determined by their geographical isolation from each other and the rest of the world, and taking into account their scarce technological and scientific human resources, should be clearly recognized and taken into consideration in the formulation of regional and subregional development assistance programmes.

76. The issue of standardization in terms of thematic classification, data format and output product specifications, had become critical, especially if the sharing of spatial information/data among agencies was considered for various applications purposes. Therefore, that issue should draw close attention from related agencies at both national and regional levels.

77. The workshop acknowledged the welcome development that EOSAT had recently made arrangements to grant a consortium the right to share the purchased Landsat data among the consortium members. Such a consortium concept should be considered by national government agencies and, when appropriate, a consortium should be established in an effort to obtain similar conditions from EOSAT. Other remote sensing satellite operators and image distributors such as SPOT IMAGE should be approached to obtain similar arrangements.

78. The workshop noted that in a number of cases the consulting agencies implementing projects in the Pacific Island countries often took away basic information generated for the projects. Furthermore, the recipient countries were often denied access to that information and were requested to pay for the data. The workshop considered that situation as unfortunate.

79. In that connection, the workshop recommended that such data repatriation issues be solved. To avoid that kind of confusion, the recipient Government should pay particular attention to the issue of data ownership and related intellectual property in accordance with international law when signing the contract. Furthermore, foreign consultancy institutions and concerned agencies should study the issue in fulfillment of the sovereign rights of nations to have access to data about their own countries in accord with common practice.

80. Many developing nations in the Pacific encountered serious problems when disasters occurred and were often denied technical assistance or funding support for remote sensing/GIS technology for emergency uses. Therefore, the Workshop strongly recommended that related international organizations, donor agencies, particularly the United Nations Disaster and Relief Operations Centre, should establish an emergency funding package to provide technical assistance for the Pacific island countries.

81. Communications facilities such as Internet, PEACESAT, PSTN (Public Switched Telephone Network), as well as through local area networks should be established and wide accessibility encouraged in order to create the opportunity for information exchange between countries of the region.

82. Technical cooperation among developing countries (TCDC) arrangements between the Pacific countries for study tours, on-the-job training, training workshops and pilot projects should be initiated and promoted in the region.

83. The Workshop strongly requested that the ESCAP secretariat enhance its activities in the Pacific subregion to assist the member countries in building national capacilities in the use of remote sensing/GIS for environmentally sound and sustainable development. It also strongly recommended that UNDP continue its partnership with the ESCAP secretariat in promoting wider remote sensing and GIS applications in the region in its future programme. It also strongly recommended that ESCAP develop its partnership with regional orgaizations working in that field to enhance delivery of services to member countries.

84. The Workshop formulated a set of project proposals for implementation under the Regional Space Applications Programme for Sustainable Development endorsed by the Ministerial Conference held in September 1994 in Beijing. The ESCAP secretariat was requested to reconcile and further detail the project proposals and subsequently present the proposals to donors for possible funding support. The United Nations system and related regional organizations were also requested to cooperate and provide assistance in the implementation of the action plan.

6. Closing

85. The Workshop was closed on 17 February 1995 by Mr B. Dutt, Permanent Secretary of the Ministry of Lands, Mineral Resources and Energy. Before the Workshop was closed, the participants and the representatives of the ESCAP secretariat once again expressed their deep gratitude to the Government of Fiji for their warm hospitality, and particularly to the national Workshop Organizing Committee for its excellent preparatory work and arrangement under the guidance of the Fiji Land Information Council.

PART TWO
REMOTE SENSING AND GIS

ENVIRONMENTAL APPLICATIONS OF GEOGRAPHICAL INFORMATION SYSTEMS

by

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1.0 Introduction

The application of Geographical Information Systems (GIS) to a diverse range of problems in environmental management and monitoring is now well established. That GIS is a powerful tool for the analysis of environmental data (although more so in the case of land than marine data) and for solving important problems has been convincingly demonstrated. There is, however, some confusion among users, especially beginners, about what is actually involved in the application of GIS. This paper uses relatively simple examples to illustrate the way in which GIS is used in environmental applications. An important distinction is made between application at two levels — the simple querying of spatial databases and more advanced cartographic modelling.

2.0 Querying spatial databases

GIS is commonly used in organisations concerned with environmental applications as a database management tool and as a means of producing maps — the end result of any GIS application. The capability of GIS to manipulate the original data to provide new information is not always fully exploited. Instead, GIS is more frequently used to search a database to answer relatively straightforward and simple questions. Although this is an important starting point there is more to using GIS than this.

When GIS is used in this way, simple questions of the 'what is?' and 'where are?' kind are asked. The answers may result simply in the production of a thematic map of a single item in the database. Examples of these kind of questions are: 'where is a particular soil type found?'; 'how large is the area covered by a particular type of vegetation?' and what is the height above sea level at aparticular place?'. Answers to these kinds of questions are obtained simply by querying a single theme (called a layer or a coverage) in the attribute database and mapping the result.

Many simple queries, however, make use of a combination of items: they involve items from more than one coverage in the database. Examples of these kinds of questions are 'Where are the places with a particular combination of attributes?' or 'What is the spatial association between two or more variables?'. There is only one answer to these kinds of queries — a map describing the existing situation.

Using GIS to answer these kinds of simple queries involves the use of selected operations but these are only used in isolation or in simple combination. Two of the most frequently used operations are *buffering* — placing a boundary at a specified distance around a spatial feature, for example drawing a boundary that encloses all places within 250 metres of a river or from a well used for drinking water, and *overlaying* — superimposing one coverage on top of another, for example to investigate the ways two things (e.g. vegetation and soil type) are associated spatially (Aronoff, 1989).

To illustrate this problem, imagine that as part of a forest management programme one is asked to answer the following kinds of questions: 'Is a greater proportion of conifer plantations in the region subject to high fire risk than native forest?': 'Which forest type in the region has the lowest level of fire risk?'; or 'How much of the region covered by forests is prone to high (or low) fire risk?'. The answer

to these kinds of questions is based on the way that the level of fire risk and the forest types (e.g. conifer plantations and native forests) are spatially associated. Two data layers are required — the coverage showing the distribution of the two types of forest (Figure 1A), and the coverage showing the distribution of the levels of fire risk (Figure 1B). Note that these are examples of *raster* coverages — the data is coded by grid cells.

The association between the two coverages is determined by overlaying one map on top of the other, a technique developed many years ago in landscape planning (McHarg, 1969). In a non-automated GIS, this requires that one of the maps be drawn on mylar or some other transparent paper, placed on top of the other, and then recording manually the covariation between the different categories on the two maps. This can quickly become a time-consuming task, particularly when there are many categories on each map. Moreover, the results are likely to be inaccurate and subject to high levels of error.

The association between the two coverages can be established quickly and with precision when the two maps are stored in digital form in a computer and manipulated using a GIS. The result is the production of an entirely new map (providing new information) showing the spatial association between the two coverages. In the example used here, this shows six different combinations based on the two forest types and the three levels of fire (Figure 1C). A table will be generated as well which indicates the number of grid cells in each association category. Using the map scale, calculating the total area for each combination required to answer the initial questions is then straightforward.

3.0 Cartographic modelling

Although querying databases in this way is important in exploring spatial data, producing maps and tables, and answering straightforward questions, it only represents the most basic and elementary use of GIS. In most realistic environmental applications much more is required than this and the functionality of GIS is utilised more fully using a process referred to as *cartographic modelling* (Tomlin, 1990). Cartographic modelling involves structuring many different GIS functions in logical sequence to work towards the solution to a given problem.

The first step in this more complex type of GIS application is to represent the sequence of operations to be carried by the GIS in the form of a flow chart in the same way one might do to solve a mathematical equation: conceptually, the procedure is identical. The difference between them is that instead of calculating a numerical value a new map is generated which forms the answer to the problem. One of the advantages this process of cartographic modelling is that the data layers required for the application can be identified at the outset. This can result in considerable savings in the cost of adding new layers to the database if the data is not already stored in the computer.

4.0 Land suitability analysis

To illustrate the process of cartographic modelling, consider the problem of assessing land suitability in a developing country for the cultivation of maize by smallholders using the Food and Agriculture Organization of the United Nations (FAO) Land Evaluation Methodology (Burrough, 1986). The FAO methodology is based on converting land attributes recorded on soil maps into a set of land qualities that are relevant for the type of land utilisation being investigated. Four factors have been identified as significant in determining the suitability of land for growing maize: nutrient supply, oxygen supply, water supply, and susceptibility to soil erosion. As with the map of fire risk (Figure 1B), these factors can be ranked into three classes according to the way they limit land suitability: no limitation, moderate limitation, and severe limitation. The resulting maps of land suitability will show these three classes of land.

Using knowledge from soil science, the four factors contributing to land suitability can be determined from the initial soil coverages. The *availability of water* is a function of soil depth and the type of soil series; *oxygen* and *nutrient availability* can be derived directly from the soil series map; and *erosion risk*

can be determined from the relationship between soil series and slope gradient. This knowledge, and the relationships between the different factors provides the bases for translating the problem into a flow chart of the procedures for determining land suitability (Figure 2).

In the flow chart, each of the boxes represents a *coverage*. Note that only three data layers are initially required to produce the map showing the distribution of the three classes of land suitability. The initial data layers (coverages) are the maps of soil depth and soil series, and a map of elevation. All of the other maps are generated from these automatically by the GIS software during the process of cartographic modelling.

Once the conceptual model has been constructed and represented in the form of a flow chart, the linkages between the different boxes are specified in terms of the commands used by the GIS software resulting in what might be thought of as a 'map algebra'. The commands are then entered in correct sequence at the keyboard and the result is the map showing the three classes of land suitability for the cultivation of maize. This final map is based on the combination of the four maps created directly from the original three coverages. Once the analysis has been set-up and the commands sequenced in the correct order, the manipulation of the individual coverages proceeds automatically for the entire area.

One of the advantages of using GIS is that the analysis can be repeated many times based on different values used to convert soil attributes to land qualities. In this way it is possible to experiment with the database and each hypothetical solution would take no more than a few minutes to generate even on a small computer. It is also possible to easily extend the analysis to take other factors into consideration, for example to assess the economic viability of cultivating maize in each of the three suitability classes. All that this requires is the extension of the cartographic model to include additional coverages and GIS operations in the flow chart.

5.0 Mapping accessibility

One of the important concepts in spatial analysis is that of *accessibility* which is simply defined as the ease of reaching a location. The mapping of accessibility is based on the price paid to overcome distance rather than physical distance itself which means that physical space must be transformed. This is commonly done by measuring distance in terms of cost, time or effort. Mapping accessibility is an important aspect of many environmental GIS applications — the example used here demonstrates how GIS can be used to map accessibility to water as part of the management strategy for the utilisation of sparse rangeland vegetation in the semi-arid zone of Australia (Zhou, 1989).

The utilisation of rangeland vegetation resources for sheep farming depends very much on the availability of drinking water, which in the area used for this case study in provided from man-made facilities rather than natural sources. Given the fact that sheep need to drink water at least once a day, it is clear that land closer to a source of water is likely to have more frequent visits by sheep than that further away and, as a result, the sparse vegetation there is likely to be overgrazed. It is also a well established fact in pastoral science that the maximum distance sheep can travel without drinking water is six kilometres.

For sheep, the accessibility to watering points is a function of distance measured in terms of the physical effort expended in moving over space. This movement is constrained by two factors. First, space is partitioned into fields each of which is fenced; secondly the land surface is not flat but is characterised by significant differences in relief. Both affect accessibility to water supplies: the fences act as *barriers* to movement which may prevent sheep from reaching the closest source of drinking water; the relief contributes to the *friction of distance* and determines the effort that needs to be expended by sheep to reach a source of water.

The conceptual model to generate the map of accessibility to watering points is shown in Figure 3. Only three coverages are initially required to find the solution: a coverage showing the location of water supply (points), one showing the location of fences (lines), and a slope map derived from a digital terrain model (polygons). The resulting maps of accessibility to the nearest watering points is shown in Figure 4. This can be compared with Figure 5 which shows what the pattern of accessibility would look like if the only factor determining the choice of a particular watering point by sheep is physical distance (i.e. the effects of barriers on movement and the frictional effect of distance are not taken into consideration).

The map of accessibility to watering points produced as a result of the process of cartographic modelling is an invaluable source of information for management purposes. Careful study of the map and interpretation of the patterns on it enable a better understanding of how the environment may potentially be used. A substantial part of the area lies beyond 4.5 kms from the nearest source of water, and some places are further away than the maximum 6 kms sheep can travel without drinking. The map shows the pattern of accessibility as it is: it is a description of the existing situation and provides the user with valuable inventory information.

Although this inventory information is essential for the proper management of the vegetative resources of the area it is not entirely sufficient. More important is the question of how the pattern of accessibility can be improved so that access to watering points is optimal. GIS can be used to explore a range of alternatives to achieve this simply by making changes to the initial coverages either by introducing additional watering points and/or rearranging the fences and then running the model again to produce a different accessibility map.

It is in this way that GIS is used to *invent* alternative scenarios for purposes of resource management. The emphasis is then not on questions of the 'what is' or 'where is' kind but on those of the 'what if' kind — what will the pattern of accessibility look like if additional sources of water are made available at location X or Y?...or if the fences are rearranged is this particular way? Given that the costs of adding additional watering points or of rearranging the fence lines can be easily calculated, the hypothetical maps of accessibility produced by the GIS may not only be evaluated cartographically but, importantly, also in terms of the costs that would be incurred if a particular strategy were to be implemented. It is in this way that GIS can be used as a tool to support decisionmaking.

6.0 Site selection

The third example illustrating the process of cartographic modelling is that of selecting potential land fill sites for hazardous waste materials. This is a problem that is becoming increasingly widespread in all countries regardless of level of economic development and one that can easily be solved using the buffering function in a GIS. The particular example is taken from a study in Thailand (Krerkpong *et al.*, 1994). The identification of sites potentially suitable for landfill is essentially based on the sequential elimination from consideration of areas that fail to meet a specified set of criteria. These are typically formulated as a set of rules that from the basis of the cartographic model. In this study, the factors that are considered to be significant in determining site suitability include distance from groundwater wells; cultural features such as schools, temples, and archaeological sites; slope of the land; land use; and geological structure.

The areas satisfying all of the criteria (the rules) are shown in Figure 6 which is the final product from the manipulation of the initial spatial database using a GIS. The solution, like those in the case of evaluating land suitability and accessibility to watering points discussed above, is a map — but in this case one with only two *discrete* classes, namely suitable areas and unsuitable areas. This is a characteristic of all maps produced by standard GIS software packages because the operations forming the cartographic model are based on the rules of Boolean algebra (Burrough, 1986). In many real-world situations, however, the concept of discrete boundaries between categories (e.g. soil types, vegetation, etc.)

is not entirely realistic. This is because boundaries between categories of environmental phenomena are typically gradational and characterised by zones of transition from one category to another. Reality is characterised by a considerable amount of "fuzziness".

Recent advances in modelling with GIS now make it possible to incorporate the notion of "fuzziness" into cartographic models to produce maps on which areas are represented according to some measure of the extent of membership in a particular category. This is achieved by replacing Boolean operations with those based on the use of fuzzy set theory. In this way, quite different and usually more realistic maps can be produced. Figure 7 illustrates this for the selection of landfill sites in Thailand. On this map areas are classified as belonging to one of six different grades of suitability for locating a landfill for hazardous waste. The areas with the highest grade of suitability are the best suited on the basis of the original set of criteria. Selection of the most suitable site (areas with an index of 1.0) may of course not be feasible because of other factors (the land is owned by the Defence Forces or is impossible to acquire). Then the next best sites can be evaluated through field investigation and the most suitable of these identified and selected.

7.0 Limitations to GIS applications

The above examples illustrate the kinds of spatial analysis based on cartographic modelling that are possible using a GIS. Although the chosen examples are simple and relatively straight-forward, the concepts and procedures involved are essentially the same in principle for more complex problems. The only real difference is that these require more complicated cartographic models based on larger data sets.

The current stage in the evolution of GIS software itself, also imposes limitations on the kinds of applications that can be addressed. This is particularly the case when *mathematical modelling* as well as cartographic modelling is required — which is often the case for environmental applications. In the case of land suitability, for example, suppose the question asked was not simply to identify the current suitability of land for a particular crop type in a region but rather to evaluate land suitability at some future time, say after 10 years of continuous cropping. The solution to this more complex problem requires additional operations to be performed than those in the simple cartographic model shown in Figure 2.

Account must now be taken of soil erosion, the effects of which are likely to become more serious as a result of intensifying agriculture. Estimates of soil losses in the future must be calculated, mapped, and incorporated into the cartographic model along with additional data layers (e.g. slope length, rockiness, etc.). Calculating soil loss necessitates the use of a mathematical model to predict the rate of erosion during the specified time period. State-of-art GIS do not have the capacity to undertake this kind of mathematical modelling, which consequently has to be performed separately. The output from the mathematical model must then be incorporated into the GIS data base as an additional data layer. The poor capability of GIS to incorporate mathematical modelling thus imposes severe limitations on the kinds of environmental problems that can be addressed using GIS *per se*.

Another serious limitation of current GIS for environmental applications arises because they do not handle 3-dimensional data very well. Although some advances have recently been made in improving the capability of GIS to handle 3-dimensional data (largely as a result of research into the application of GIS in solid geology and geoscience — see Raper, 1989), most GIS softwares are restricted to the manipulation of 2 dimensional — or what is commonly referred to as 2.5-dimensional data (e.g. that used in digital terrain modelling). The capability of current GIS to handle 4-dimensional data is very poor indeed (Townsend, 1991).

This shortcoming in particular is, of course, what makes it extremely difficult to use GIS effectively in many marine applications which involve the modelling of solid water bodies including movements within these (e.g. currents, fish stocks, pollution plumes, etc.) through *time*. Time is a fundamental

consideration in all process-orientated environmental applications. Information describing change over time in attributes, their distribution, and their interrelationships is essential for resources management and environmental monitoring for sustainable development. Research into temporal database design and temporal GIS applications is still very much in its infancy (Langran, 1989).

8.0 Conclusion

This paper has attempted through the use of relatively simple and straightforward examples to demonstrate some of the ways in which GIS may be used in environmental applications. The strength of GIS lies in their ability to manipulate data in a logically structured way through the sequencing of many different functions that is referred to as the process of cartographic modelling. The concepts and procedures involved — once grasped and understood — can be applied by extension to more complex situations without difficulty.

Two important considerations, however, need to be kept in mind. First, the reliability of the results of all cartographic modelling are only as good as the initial data permits. The design and construction of environmental data bases is therefore a crucial factor for all GIS applications, whether these relate to natural or human resources management. Users must be familiar with the sources of spatial data and data problems (see Fiser, 1991), have a good understanding of the error component in spatial data, and particularly the way error in data is propagated as a result of data manipulation (Chrissman, 1991).

Secondly, users should never lose sight of the fact that GIS are only a tool for spatial analysis. They permit the efficient management of spatial databases, speedy and accurate manipulation of data, and the visualisation of these on maps. The effective use of GIS, however, still requires a specialist knowledge-base in a particular branch of environmental science. Without that, it is not possible to structure problems correctly, formulate cartographic models appropriately, or realistically interpret the results of GIS applications. The latter is especially significant: without the ability to adequately interpret the results of the application of GIS it is not possible to gain the insights and understanding that are essential for environmental management and policy making.

The fundamental value of GIS for environmental modelling, monitoring and management is, however, the potential they have to generate scenarios of alternative futures. To paraphrase the words of Burrough (1986, p. 85), rather than letting environmental planners loose in situations in which they may have little or no experience, it is preferable to train them on digital models of the environment. Just as pilots are trained to fly using flight simulators and architects build *maquettes* in order to develop their concepts and ideas, so environmental planners and managers can learn from mistakes made using digital landscapes before making irrevocable errors in the landscape itself.

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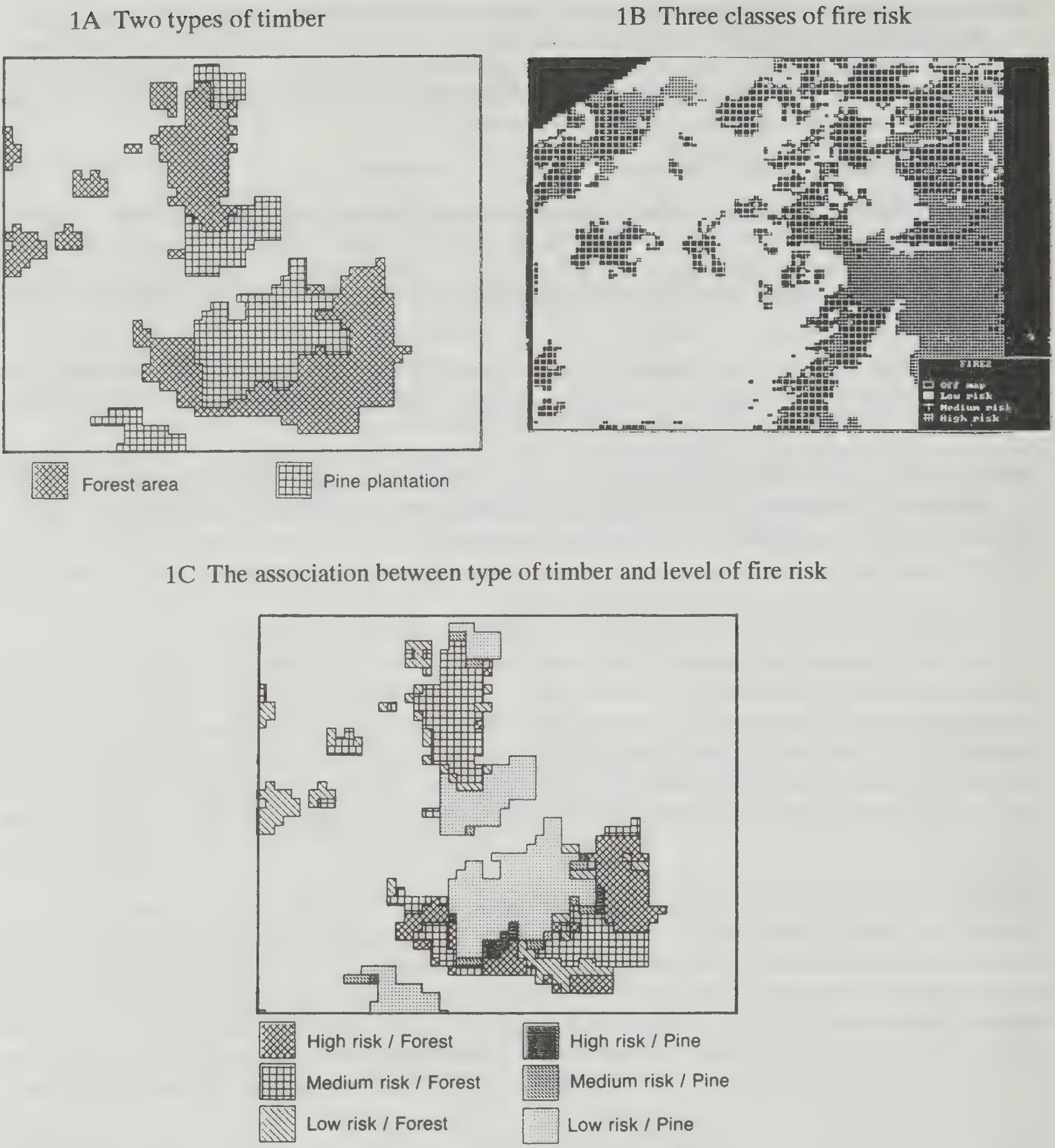

Figure 1. Using GIS to identify spatial associations

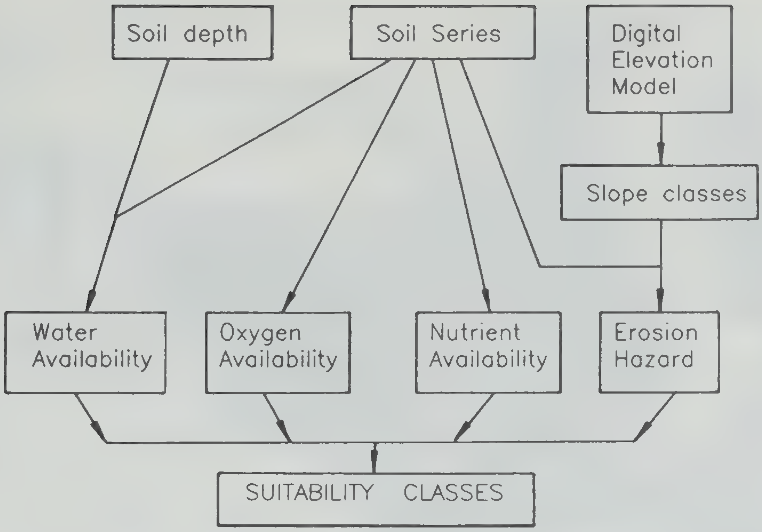

Figure 2. The cartographic model used to determine land suitability for maize (after Burrough, 1986).

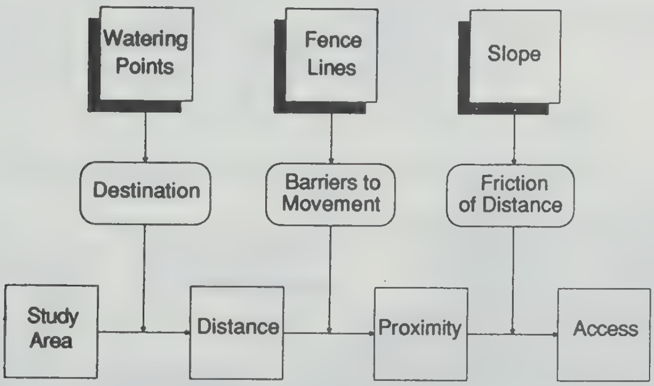

Figure 3. The conceptual model used to map accessibility to watering points

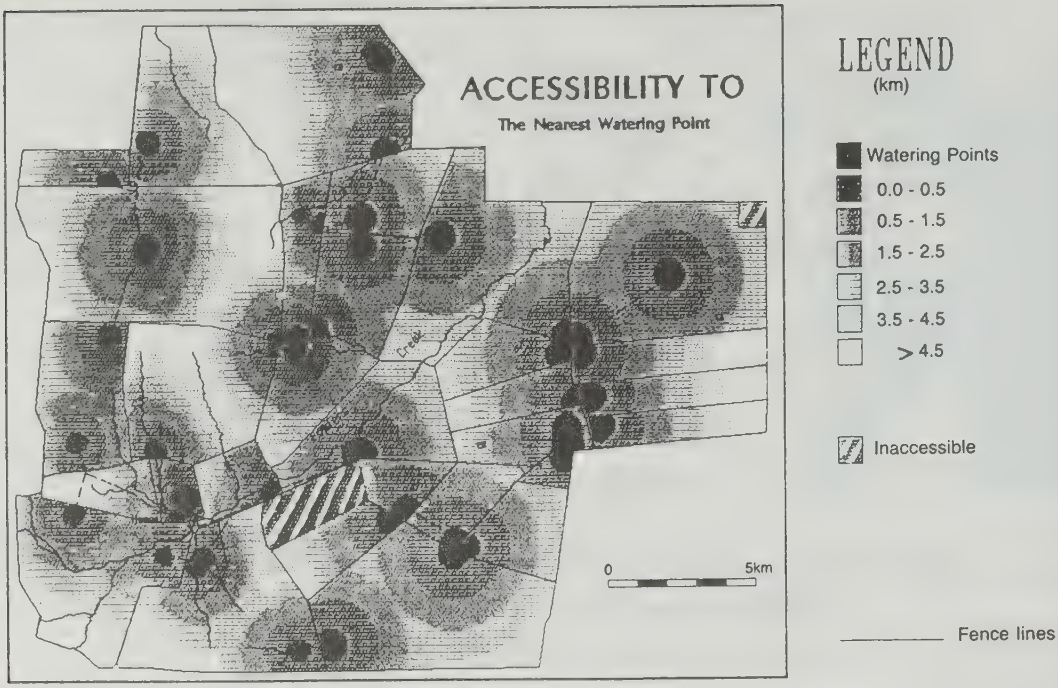

Figure 4. Accessibility to watering points

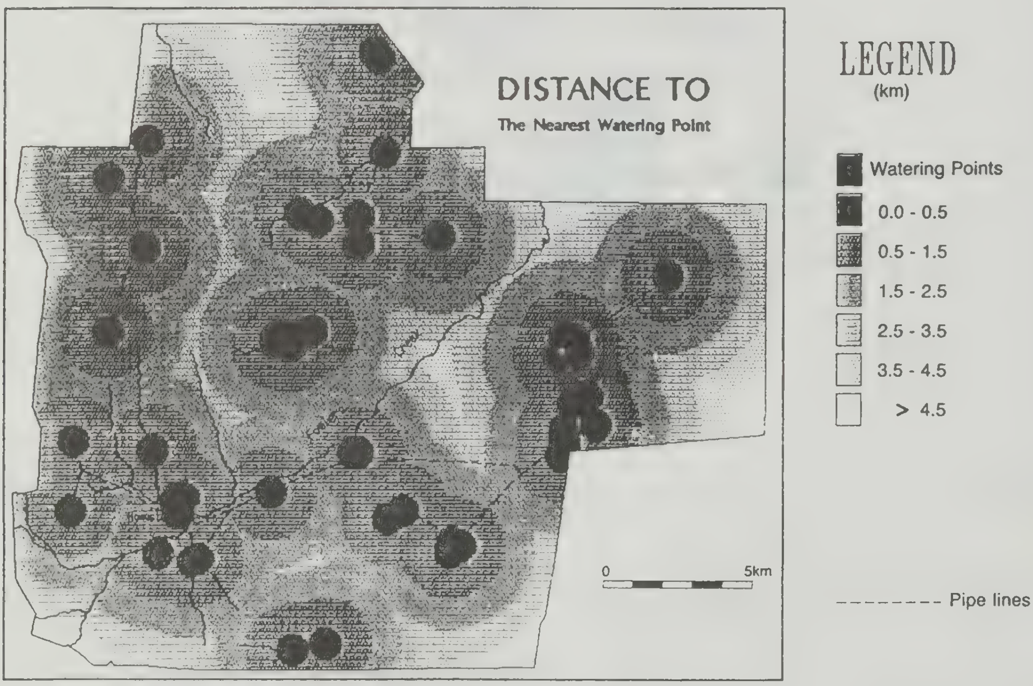

Figure 5. Simple distance to watering points

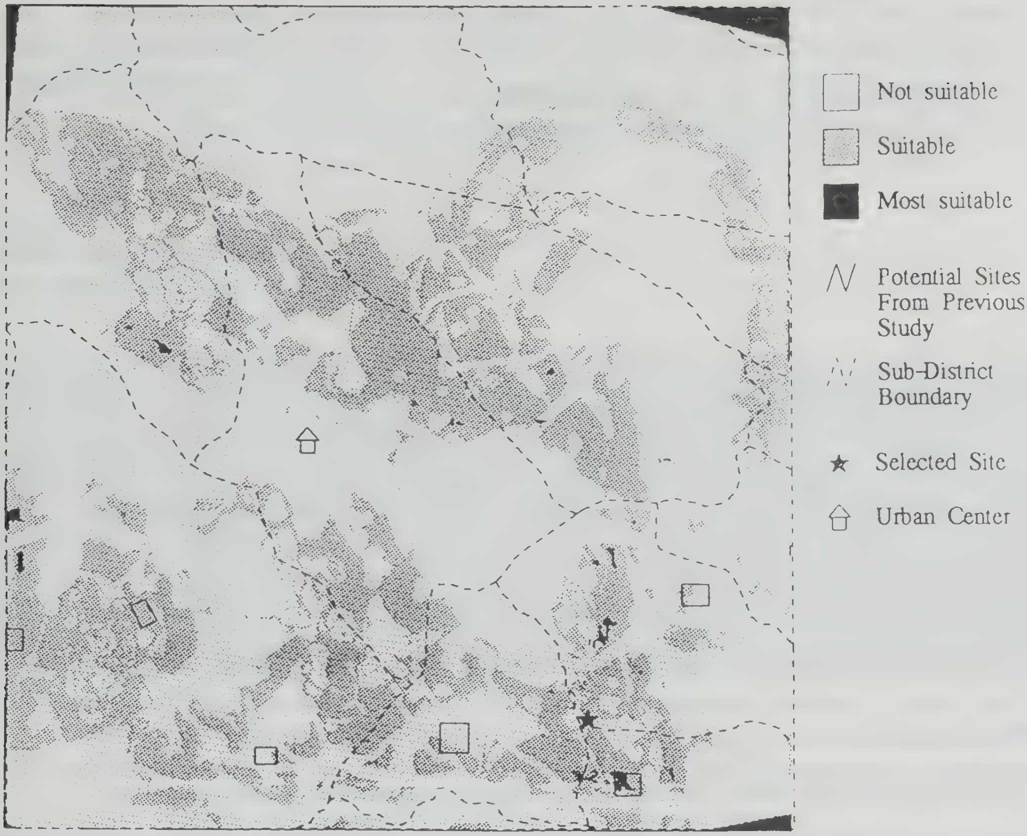

Figure 6. Suitable landfill sites based on Boolean modelling in GIS

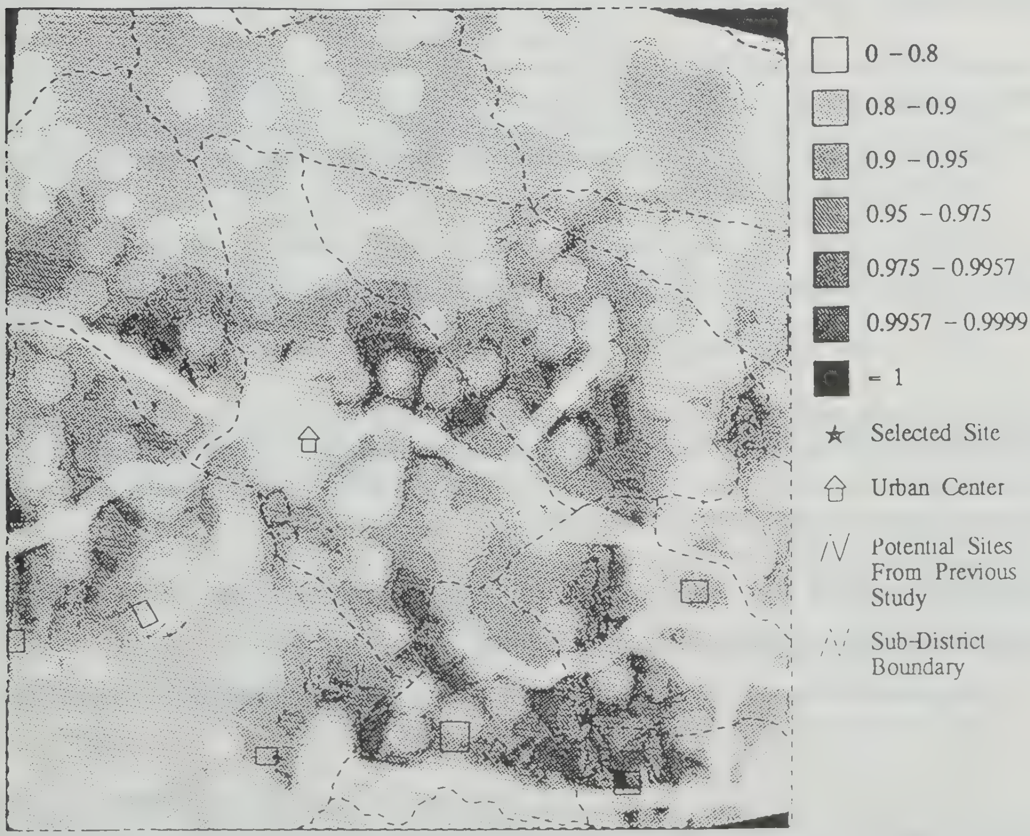

Figure 7. Suitability of areas for the location of landfill sites based on fuzzy logic

INTRODUCTION TO GEOGRAPHICAL INFORMATION SYSTEMS*

by

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ABSTRACT

A GIS is a particular form of information system applied to geographical data. It is a powerful tool to input, store, manipulate, analyse, model and output spatial and attribute information. The ultimate goal of a GIS is to support decision-making in, for example, natural resources and environment management, urban and regional planning, and any other activities which have a spatial context. Implementation of GIS technology is often a complicated task which involves a careful planning, selecting of computer hardware and GIS software, and resolving many organisational issues and problems.

1.0 GIS concepts

1.1 A GIS is a particular form of information system applied to geographical data

A *system* is a group of connected entities and activities which interact for a *common pupose*. An information system is a set of processes, executed on raw data, to produce information which will be useful in *decision-making*.

Geographical data include those which are *spatially referenced*. Geographical data contains four important aspects:

1. *Spatial locations* — locations of spatial objects which are specified by a geographical coordinate system (a map projection);

2. *Attributes* — descriptive information about the spatial objects of interest;

3. *Spatial relationships* — quantitative or logical relationships between spatial objects; and

4. *Time* — time of data acquisition and life of the spatial and attribute data.

A GIS uses geographically referenced data as well as non-spatial data and includes operations which support spatial analysis and modelling. In GIS the common purpose is decision-making, for managing use of land, resources, transportation, retailing, oceans or any spatially distributed entities. The connection between the elements of the system is geography.

1.2 Components of GIS

A complete GIS have three components, namely:

1. Computer hardware — the machinery of the system including Central Processing Unit (CPU) and peripherals such as input and output devices;

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2. GIS software modules — software to support spatial information handling including data input, database management, data manipulation and transformation and data output including automated mapping;

3. Organisation aspects — organisational implementation of GIS which incorporate GIS into usual decision-making processes.

2.0 Technical and organisational considerations

2.1 Hardware considerations

As a GIS is a quite complicated system, the hardware developments can never be a stand-alone issue in GIS development. Therefore selection and management of GIS hardware are closely related to the proposed GIS software system, available computing and personnel resources and, in many cases, historical factors in the organisation.

Typically selection of GIS hardware involves considerations on types of computers, data storage, visualisation and input and output capabilities.

2.1.1 Type of computers

For a GIS, the type of computers is largely related to the proposed applications of the system, GIS software to be used, available computing staff and expertise in the organisation and, of course, the funds available for the GIS project. Generally speaking, there are three classes of computers which are used in today's GIS projects around the world, namely, personal computers (PCs), workstations, and mainframe super computers:

- *Personal computers* are usually used by a single user and perform a single task (doing one thing at a time). Although today's personal computers have evolved to supply a very high processing power, it is typical that GIS based on personal computers are regarded as low power systems and can only be used to handle small GIS databases.

- *Workstations* are the choice of computer type for today's GIS. They typically run a version of UNIX operating system supporting multiple users (though typically used only by one major user) and performing multiple tasks (doing several things at a time). This type of computers is usually equipped with high performance graphics and fast network devices.

- *Mainframe super computers* are those providing super computing power and typically employ multiple CPU and parallel processing capabilities. They are mainly used to handle very large spatial databases and support complicated spatial data analysis tasks.

2.1.2 Data storage

Computer data storage devices are vital for GIS hardware consideration. These can be classified as two major groups, namely, 'soft' storage and 'hard' storage:

- 'Soft' storage is the storage device to temporarily hold data. This kind of storage provides very fast access speed and typically has a high price. A example of this is the Random Access Memory (RAM) which supports temporary data storage between CPU and 'hard' storage devices.

- 'Hard' storage is storage devices which can hold data permanently (e.g. Hard Disk, Magnetic Tapes, CD-ROM, etc.).

2.1.3 Visualisation

Visualisation capabilities is important for GIS applications which are typically very graphics oriented (e.g. making maps). A GIS can present its graphical output in three forms: soft copy, hard copy and electronic:

- *Soft copy* (e.g. on-screen display) presents graphics output temporarily at a high speed with a high refreshing rate. Output of this kind may be temporarily visualised but cannot be stored permanently.
- *Hard copy* (e.g. printed paper maps) presents graphics output permanently at a relatively slower speed. This usually uses media such as paper, transparency or films to draw graphics output which can then be carried away without using a computer.
- *Electronic* (e.g. data metafiles) is mainly used for graphics output transfer through data storage media or network.

2.1.4 Peripherals

Input devices

Common input devices for a GIS include digitisers, map scanners and mouse. Digitisers and map scanners are used to capture graphics data from analogue maps and convert the data into a digital format. A mouse is becoming an essential part of a computer and used as one of the major tools for the user's interaction with the computer.

Digitiser tablets are still the most popular input device for GIS. These tablets normally support a device resolution up to 0.01 mm and the size varies from 12 by 12 inch (30 x 30 cm) to about 40 by 30 inches (108 x 76 cm). Manual digitising is the method using these digitiser tablets and the data quality derived from a digitiser tablet is largely dependent upon the software used and the operator's qualification.

Map scanners are important devices for automatic spatial data capture. They are significantly more expensive and technical and financial requirements for GIS software are significantly more critical than digitiser tablets. Usually scanned map data is of better quality than those acquired through manual digitising, particularly for those from complicated maps.

Output devices

Common output devices include printers, plotters and film recorders. The obvious tasks of these devices are map data production in the forms of hardcopy.

Printers are commonly used devices for both character and graphical output from GIS. Although old character-based *line printers* are still used for GIS data output, various graphical printers have already become the major tools for map data output. Among these, the cheapest type is the *dot-matrix printers* but the most commonly used in a low-end GIS figuration are various types of black and white *laser printers*. Colour printers using *inkjet, thermal wax transfer* or *dye sublimation* techniques are becoming popular to support high-resolution, small format, colour map and image output. *Inkjet* or *Electrostatic* printers are used to support high-resolution, large format, colour map output. As they are much more expensive devices and the maintenance cost is also very high, they are mostly used in large map production projects.

Pen plotters are also common devices for map output. They are cheaper devices for producing large format map output than printers. However, the output speed is generally slow and the number of colours supported is much less than colour printers. Therefore the pen plotters are commonly used in relatively small GIS projects to support large format and relatively simpler map output.

Film recorders are used to produce photographic output from GIS. They are capable of producing very high quality graphics output on film media. However, the cost for a film recorder as well as running costs very high.

2.2 *Software considerations*

A complete GIS software system includes functions to support spatial data input, storage and retrieval, manipulation and transformation and output. Selection of GIS software is a usually much more complicated and critical task compared with hardware selection. Typical considerations for GIS software selection include capability, compatibility, expandability, ease of use and cost efficiency.

2.2.1 Capability

Capability of a GIS software is judged by its capabilities for handling large databases, processing different kinds of spatial and attribute data, and presenting a high quality of graphics output. It is also judged by its capability to provide powerful data processing tools and macro languages to cover specific application demand. As GIS applications can be in many completely different fields, there is no 'perfect' GIS software which can cover all possible GIS application.

2.2.2 Compatibility

This is usually very critical. As databases (including spatial and attribute databases) usually exist in the organisation or are acquired from existing sources, it is crucial for GIS to be able to access these existing data sets. It is also important ot understand that data sharing between organisations will also demand that compatible systems are run in those organisations where large amounts of data is or will be shared.

2.2.3 Expandability

Spatial and attribute databases will expand to cover larger areas, incorporate more information or gather more details. Demand on data processing power may also occur after the initial implementation of GIS in an organisation. It is important, therefore, to ensure that GIS software can cope with the possible increasing demand in the future.

2.2.4 Ease of use

Whatever powerful GIS is developed, it needs to be used to realise its benefit. The user, therefore, is the most crucial part of GIS implenentation. It is the software developer's responsibility to provide a user-friendly interface to ease the learning process for the end user.

2.2.5 Cost efficiency

Cost and benefit analysis should always be applied when implementing a GIS in an organisation. The cost is not only the software cost, but also requirements on hardware, technical support and staff training. In many circumstances, cheaper software packages may or may not provide the overall cost efficiency.

2.3 *GIS personnel*

The most improtant component of a GIS is GIS personnel — the people who use the system, maintain databases, provide technical support and, more importantly, make decisions using the system. In general, GIS personnel include the follows:

- *Operators* — people who carry out daily system operations such as data input, updating, etc., requiring low-level, task specific training.
- *Technical supporting staff* — usually a system engineer who installs and maintains GIS software, hardware and large spatial databases, and provide technical support to the end user.
- *Application specialists* — application experts who design GIS application models and specify output requirements for decision-making.

- *External consultants* — use of external consultants often provides a cost effective approach to gain expert input to the application fields and to introduce the new technology into the organisation.

- *Decision makers* — people who make decisions based on the information provided by GIS. Training needs to be provided to these decision makers on the awareness of the technology and capabilities and benefit of GIS.

2.4 Data considerations

Data is often critical for a GIS implementation. As data volume of a spatial databases is often very large with complex data structure, to adequately acquire and maintain required data sets is a vital task of a GIS project.

Data requirements for a GIS project must be carefully studied before acquiring hardware and software. The limitation of data availability and cost are often prohibitive factors for a GIS implementation, particularly those related to natural resource and environmental applications.

Spatial and attribute data are required for resource and environmental applications. Spatial data typically include various kinds of maps, ground survey data and remotely sensed imagery. Attribute data often include various types of administration records, census, field sample records and collections of historical records.

In establishing GIS database, it is important to accurately register spatial information into a common map coordinate system and to correctly link spatial locations into their corresponding attribute records. These tasks are often time consuming and error prone, and require a high level of GIS and database management expertise.

2.4.1 Vector and raster data structures

It is often critical to formalising data structure for a GIS database. For today's GIS, spatial data structure is one of the two common choices:

- Vector structure which records spatial variation using spatial objects such as points, lines and polygons; and

- Raster structure which records spatial variation using grids or images.

None of these data structures can supersede the other in all aspects of GIS applications and there is no real technical difficulties to convert spatial data from one data structure to the other. Therefore, it is common for today's GIS to support both data structures and it is not unusual to establish a GIS database which contains both vector and raster data. A general comparison between the two data structure is outlined in Table 1.

2.5 Data sources and quality

2.5.1 Data sources

Spatial data are usually available in the forms of existing analogue maps (through digitisation), existing digital databases and ground survey data. However, the current trend is the development of large shareable databases which is created, maintained and distributed by government organisations or commercial bodies.

Attribute data such as census, statistical tables and reports are often available in digital forms in various administration databases or through commercial distribution networks.

Table 1. Comparison of Raster and Vector Data Models

Raster model	Vector model
Advantages:	**Advantages:**
1. It is a simple data structure.	1. It provides a more compact data structure than the raster model.
2. Overlay operations are easily and efficiently implemented.	2. It provides efficient encoding of topology, and as a result, more efficient implementation of operations that require topological information, such as network analysis.
3. High spatial variability is efficiently represented in a raster format.	3. The vector model is better suited to supporting graphics that closely approximate hand-drawn maps.
4. The raster format is more or less required for efficient manipulation and enhancement of digital images.	
Disadvantages:	**Disadvantages:**
1. The raster data structure is less compact.	1. It is a more complex data structure than a simple raster.
2. Topological relationships are more difficult to represent.	2. Overlay operations are more difficult to implement.
3. The output of graphics is less aesthetically pleasing because boundaries tend to have a blocky appearance rather than the smooth lines of hand-drawn maps. This can be overcome by using a very large number of cells, but may result in unacceptably large files.	3. The representation of high spatial variability is inefficient.
	4. Manipulation and enhancement of digital images cannot be effectively done in the vector domain.

Source: Aronoff, S., 1989. *Geographical Information Systems: A Management Perspective*, WDL Publications, Ottawa.

2.5.2 Data quality

Data quality of existing spatial and attribute data are often variable. It is important to gain data quality documentation for a specific data set acquired. Unfortunately this kind of document is not always available.

Accuracy and precision of spatial data are often the control factors on the scale of GIS application. It is obvious that data sets with the lowest accuracy and precision in a spatial database is often the determining factor on the accuracy of the data processing output.

Data generalisation and conversion often cause loss of accuracy for spatial data. The consequences of such generalisation and conversion must be carefully analysed against the overall goal of data processing to prevent unnecessary data loss.

3.0 Analysis and modelling

3.1 Analysis or modelling?

The advantage that a GIS can provide is the capability for transforming the original spatial data in order to answer user-specified queries. Such transformations are often referred to as "data analysis" capabilities in a GIS context. However, a distinction can be made between transformations that are *analytical* and those that involve the *synthesis* of information. Such distinction can be described as the "analysis", the process to resolve and separate the reference system (such as the surface of the earth) into its parts to illuminate their nature and interrelationships, and to determine general principles of behaviour. The "synthesis" is the process to put together expressions of these general principles with representations of parts of the reference system so as to form a replica that exhibits behaviour similar to that of the reference system. A theory is the product of analysis, whereas a model is the product of synthesis, using theory.

Geographical analysis allows the study of real-world processes by developing and applying models. Such models illuminate underlying trends in the geographical data and thus make new information available. A GIS enhances this process by providing tools which can be combined in meaningful

sequences to develop new models. These models may reveal new or previously unidentified relationships within and between data sets, thus increasing our understanding of the real world.

Results of geographical data analysis can be communicated with maps, reports, or both. A map is best used to display geographical relationships whereas a report is most appropriate for summarising the tabular data and documenting any calculated values.

Analysis functions with vector-based GIS are not quite the same as with raster GIS. There are more operations that deal with objects and measurements, such as areas that have to be calculated from coordinates of objects instead of counting cells as in raster GIS. Compared with raster GIS, some of the vector GIS operations are more accurate (e.g. estimates of area based on polygons are more accurate than counts of pixels; and estimates of perimeter of polygon are more accurate than counting pixel boundaries on the edge of a zone), some are slower (e.g. overlaying layers and finding buffers) and some are faster (e.g. finding path through road network).

3.2 Typical GIS capabilities

For the purpose of this article, it is impossible to outline all kinds of GIS capabilities. Therefore, examples of typical GIS capabilities which are commonly available in most of today's GIS software are presented.

3.2.1 Display and query

Display

Vector GIS displays the locations or all objects stored using points and "arcs". Attributes and entity types can be displayed by varying colours, line patterns and point symbols (Figure 1). Using vector GIS, one may display only a subset of the data. For example, one may select all political boundaries and highways, but only areas that had urban land uses.

Relational query

Different systems use different ways of formulating queries. Structured Query Language (SQL) is used by many systems. It provides a "standard" way in querying spatial databases.

Using relational queries, the user can select objects of interest and produce map output using colours, symbols, text annotations, etc.

3.2.2 Topological overlay

Suppose individual layers have planar enforcement, when two layers are combined, or *overlaid* or *superimposed*, the result must have planar enforcement as well. In this case, a new intersection must be calculated and created wherever two lines cross and a line across an area object will create two new area objects. *Topological overlay* is the general name for such a overlay followed by planar enforcement.

When topological overlay occurs, spatial relationships between objects are updated for the new, combined map. However, in some circumstances, the result may be information about relationships (new attributes) for the old maps rather than the creation of new objects.

Point-in-polygon

Point-in-polygon algorithm overlays point objects on areas and compute the "is contained in" relationship. The result is a new attribute for each point specifying the polygon it belongs to (Figure 2)

Line-on-polygon

Line-on-polygon algorithm overlays line objects on area objects and compute the "is contained in" relationship. Lines are broken at each area object boundary to form new line segments and a new attribute is created for each output line specifying the area it belongs to (Figure 3).

3.2.3 Polygon-on-polygon (Polygon overlay)

Polygon-on-polygon algorithm overlay two layers of area objects. Boundaries of polygons are broken at each intersection and new areas are created (Figure 4).

During polygon overlay, many new and smaller polygons may be created, some of which may not represent true spatial variations (Figure 5). These small un-wanted polygons are called *sliver* or *spurious* polygons. The problem cannot be removed by more careful digitising since more points in digitising simply lead to more slivers. To solve the problem, a tolerance value may be set and the spurious polygons may be deleted during overlay operations.

3.2.4 Buffering

A buffer can be constructed around a point, line or area. Buffering algorithm creates a new area enclosing the buffered object (Figure 6). The applications of this buffering operations include, for example, identifying protected zones around lakes and streams, zones of noise pollution around highways, service zones around bus route, or groundwater pollution zones around waste site.

3.2.5 Digital terrain modelling

Surfaces such as the surface of the earth are continuous phenomena rather than discrete objects. In other words, to fully model the surface, one would need an infinite number of points which in turn require an infinite data storage — an impossible task for any digital system. Thus, our purpose is to represent the continuous surfaces in a digital form using a **finite** amount of storage. To meet this demand, the digital terrain modelling techniques have emerged.

The term *digital elevation model* or *DEM* is frequently used to refer to any digital representation of a topographic surface. It is, however, most often used to refer specifically to a raster or regular grid of spot heights. The term *digital terrain model* or *DEM* may actually be a more generic term for any digital representation of a topographic surface.

A DTM may be understood as a simplest digital representation of a portion of the earth's surface, but it is perhaps the most commonly used. As the overhanging cliffs and faults are relatively rare in nature, topographic surfaces are most often represented as 'fields' (i.e. simply connected surface models, having unique z-values over x and y). In this sense a DTM is a '2.5-D' rather than a 3-D model. In a more general sense, a DTM may be used as a digital model of any single-valued surface (e.g. geological horizons and even air temperature or population density).

The input data, data models and algorithms required by digital models of terrain or other surfaces are quite different from those used in representing planimetric (i.e. two-dimensional) data. The activity of modelling and processing digital terrain data may thus be regarded as a system component of GIS that is functionally disparate from modelling 2-D data, yet needs to be closely linked to other processing functions of GIS (e.g. polygon, network and raster processing).

The most frequent use of general geomorphometry is the derivation of slope values from DTMs. Other uses of DTM include interpretation of landform features ("terrain positioning") and derivation of drainage networks.

Slope

Slope is a vector, i.e. it has a direction and length. A common algorithm to calculate slope is the one generating slope and aspect values from its 'normal vector' (Figure 7).

Calculation of slope:

$$\text{slope} = 100\sqrt{\left[\frac{\Delta H_x}{\Delta x}\right]^2 + \left[\frac{\Delta H_y}{\Delta y}\right]^2}$$

where ΔH_x and ΔH_y denote the local relief within the neighbourhood along the west-east and south-north directions, respectively; and Δx and Δy denote the distances of the neighbourhood along west-east and south-north directions. An example slope map generated from DTM is shown in Figure 8.

Aspect

Aspect is the direction of the normal vector in degrees clockwise from North.

Categories of aspect:

North:	337.5° – 22.5°	Northeast:	22.5° – 67.5°
East:	67.5° – 112.5°	Southeast:	112.5° – 157.5°
South:	157.5° – 202.5°	Southwest:	202.5° – 247.5°
West:	247.5° – 292.5°	Northwest:	292.5° – 337.5°

Calculation of the aspect:

$$\text{aspect} = 90 - \frac{180}{\pi}\arctan\left[\frac{\Delta H_y/\Delta y}{\Delta H_x/\Delta y}\right] \qquad \text{for } \frac{\Delta H_x}{\Delta x} < 0$$

or $$\text{aspect} = 270 - \frac{180}{\pi}\arctan\left[\frac{\Delta H_y/\Delta y}{\Delta H_x/\Delta y}\right] \qquad \text{for } \frac{\Delta H_x}{\Delta x} > 0$$

or $$\text{aspect} = 0 \qquad \text{for } \frac{\Delta H_x}{\Delta x} = 0 \text{ and } \frac{\Delta H_y}{\Delta y} < 0$$

or $$\text{aspect} = 180 \qquad \text{for } \frac{\Delta H_x}{\Delta x} = 0 \text{ and } \frac{\Delta H_y}{\Delta y} < 0$$

An example aspect map generated from DTM is shown in Figure 9.

Relief shading

The method of relief shading (also called hill shading) has been developed by cartographers as an important technique to improve the visual qualities of maps, particularly with respect to portraying relief differences in hilly and mountainous areas. However, old manual methods of relief shading relied on hand shading and airbrush techniques to produce the desired effect, thus they were expensive and very dependent upon the skills of the cartographer. With the development of computer technology, when DTM became generally available, the techniques of automatic relief shading emerged.

The relief shading model makes use of the optical theory (Lambert's Cosine Law) which states that the brightness of any small area of a perfectly diffuse undulating surface varies as the cosine of the angle of incident parallel light.

Calculation of per cent intensity of reflected sun light:

$$I = \frac{100}{c}\left[\sin \phi - \frac{\partial z}{\partial x} \sin \alpha \cos \phi - \frac{\partial z}{\partial y} \cos \alpha \cos \phi \right]$$

where I is the amount of sunlight reflected by a surface element; α and ϕ denote azimuth and elevation of the sun, respectively (see Figure 10); c can be calculated using the following equation:

$$c = \sqrt{1 + \left[\frac{\partial z}{\partial x}\right]^2 + \left[\frac{\partial z}{\partial y}\right]^2}$$

3.2.6 Spatial and process modelling

The real world is much more complicated than a computer can simulate. A GIS always has its limitation for its data processing capability to address specific data processing requirements. However, the spatial relationships and processes of real world elements can be separated to form a series of simpler processes which can be simulated.

GIS provides capabilities to simulate these simpler processes separately and then integrate the results together to answer complex questions. This process is also called 'cartographic modelling' which often involves separating problems into a sequence of simpler questions which are then answered using a sequence of GIS operations. The results of this cartographic modelling process are often represented by existing data sets and a sequence of data processing procedure which transform input data into required output (or intermedium) data layers. The procedure is normally implemented by a macro language supported by a particular GIS software to allow automatic execution of the model.

3.3 GIS analysis procedure

Before starting any analysis, one needs to assess the problem and establish an objective. It is important to think through the process before making any judgements about the data or reaching any decisions; ask questions about the data and modelling; and generate a step-by-step procedure to monitor the development and outline the overall objective. The following steps outline the basic procedure for geographical analysis using a vector GIS:

1. *Establish the objectives and criteria for the analysis.* Define the problem and then identify a sequence of operations to produce meaningful results.

2. *Prepare the data for spatial operations.* Prepare all map coverage for the proposed data analysis. Add one or more attributes to coverage in the database if necessary.

3. *Perform the spatial operations.* Perform the spatial operations and combine the coverage, e.g. creating buffering zones around features, manipulating spatial features and performing polygon overlay.

4. *Prepare the derived data for tabular analysis.* Make sure the feature attribute table contains all the items needed to hold the new values to be created.

5. *Perform the tabular analysis.* Calculate and query the relational database using the model defined in step 1.

6. *Evaluate and interpret the results.* Examine the results and determine whether the answers are valid. Simple map displays and reports can help in this evaluation.

7. *Refine the analysis as needed.*

4.0 Costs and benefits of GIS

GIS is a power tool to handle spatial information and potentially can bring significant benefit to the organisation. However, GIS also requires very significant investment including costs which may be measured by monetary values (e.g. hardware, software and data) and which may not (e.g. impact to the organisation and change of decision making processes). This makes a general cost and benefit analysis of GIS a very difficult task.

However, according to the levels of complexity of tasks which may be carried out by GIS, some examples of such analysis may be shown as follows:

4.1 GIS as a mapping tool

The GIS is used to input raw data and produce hard copy maps without further processing. As significant investment needs to be made to input large amounts of spatial and attribute data into the system for simple mapping tasks, the benefit of this kind of task is often insignificant. However, as a digital database has been established, the follow-up map updating and reproduction tasks will become much more cost efficient.

4.2 GIS as a spatial database management system

The GIS is used to input raw data and produce a database for query and display interactively. This use of GIS is typical for various kinds of land information systems and have been providing significant benefit for land management. Database is used to improve the efficiency of land management tasks which cand well justify the initial investment.

4.3 GIS as decision support tool

The GIS is used to input raw or processed data and theory and produce more direct information for decision making. This often involves very complicated data processing techniques and scientific or socio-economic hypotheses. The initial investment is at the same level of other tasks but the following-up investment on research and expertise is higher. However, the strength of GIS technology can be maximally realised in this kind of application and both short-term and long-term return of investment are often very significant.

5.0 Conclusion

GIS is a powerful tool for handling spatial and attribute data. It has been widely used for natural resource and environment management around the world. The benefit brought by using GIS is significant. Careful plans and cost/benefit analyses, however, are essential to implement the GIS technology.

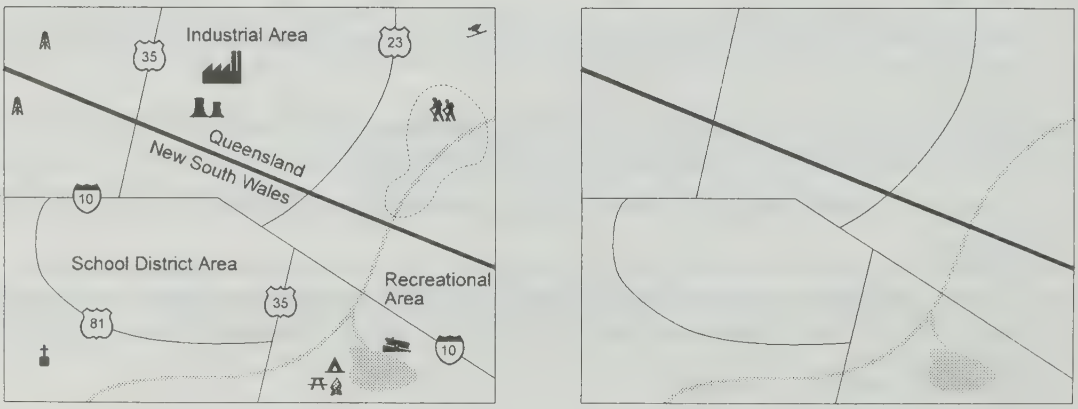
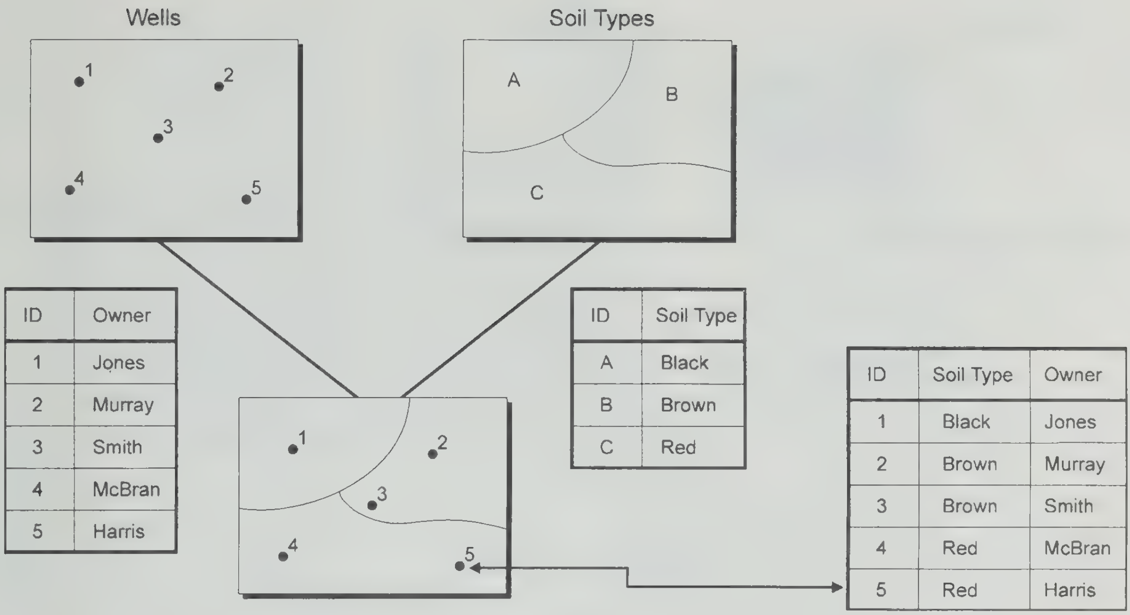


Figure 1. GIS display

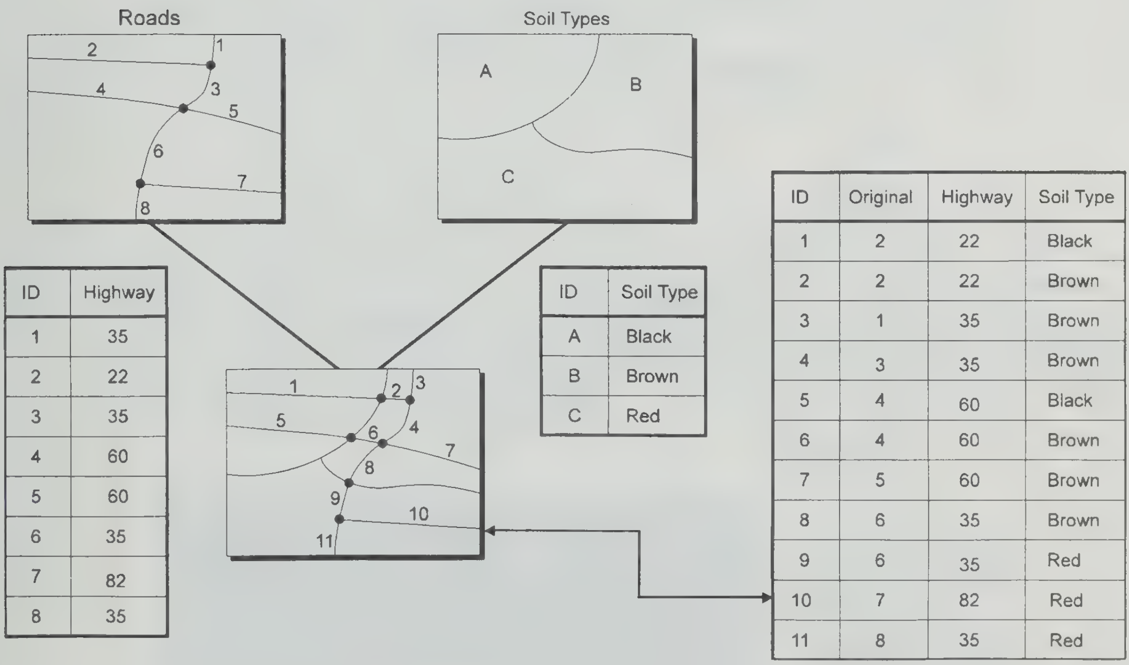


ID	Owner
1	Jones
2	Murray
3	Smith
4	McBran
5	Harris

ID	Soil Type
A	Black
B	Brown
C	Red

ID	Soil Type	Owner
1	Black	Jones
2	Brown	Murray
3	Brown	Smith
4	Red	McBran
5	Red	Harris

Figure 2. Map overlay – point in polygon

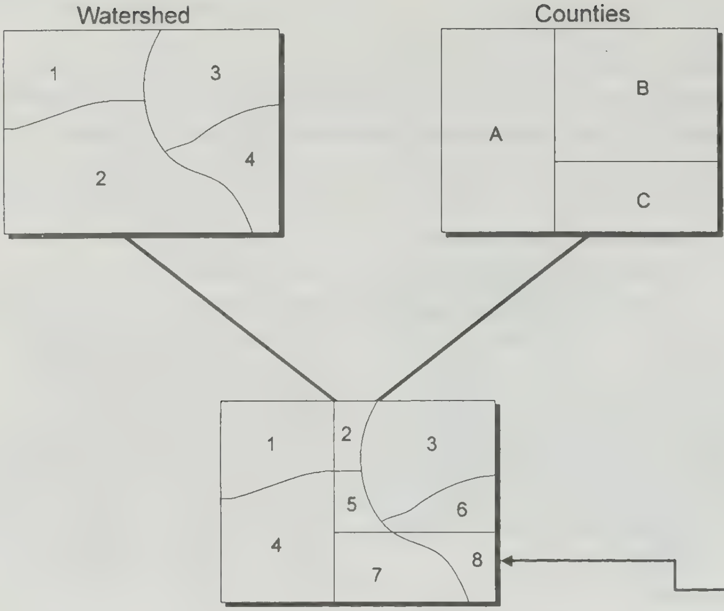


ID	Highway
1	35
2	22
3	35
4	60
5	60
6	35
7	82
8	35

ID	Soil Type
A	Black
B	Brown
C	Red

ID	Original	Highway	Soil Type
1	2	22	Black
2	2	22	Brown
3	1	35	Brown
4	3	35	Brown
5	4	60	Black
6	4	60	Brown
7	5	60	Brown
8	6	35	Brown
9	6	35	Red
10	7	82	Red
11	8	35	Red

Figure 3. Map overlay – line on polygon



ID	Watershed ID	County ID
1	1	A
2	1	B
3	3	B
4	2	A
5	2	B
6	4	B
7	2	C
8	4	C

Figure 4. Map overlay – polygon on polygon

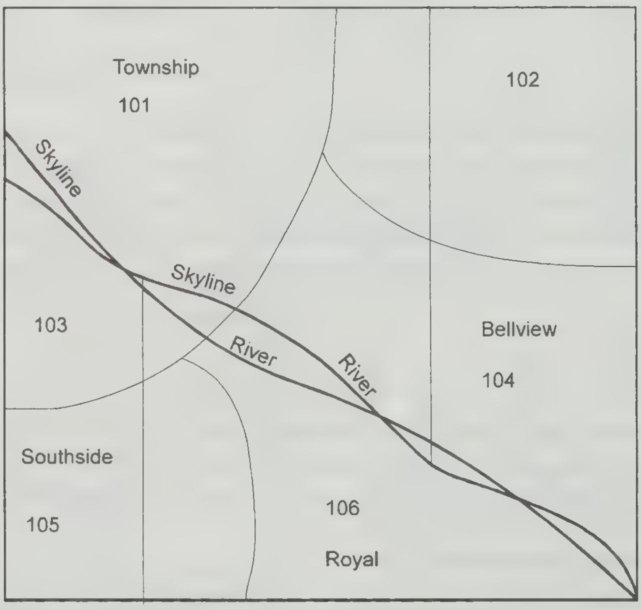
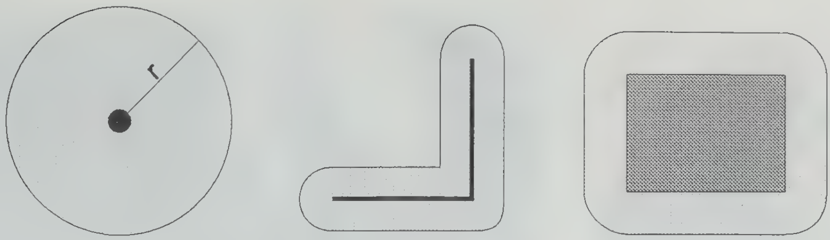


Figure 5. Sliver or spurious polygons



Buffering a point

e.g. All area within
10 km to a city

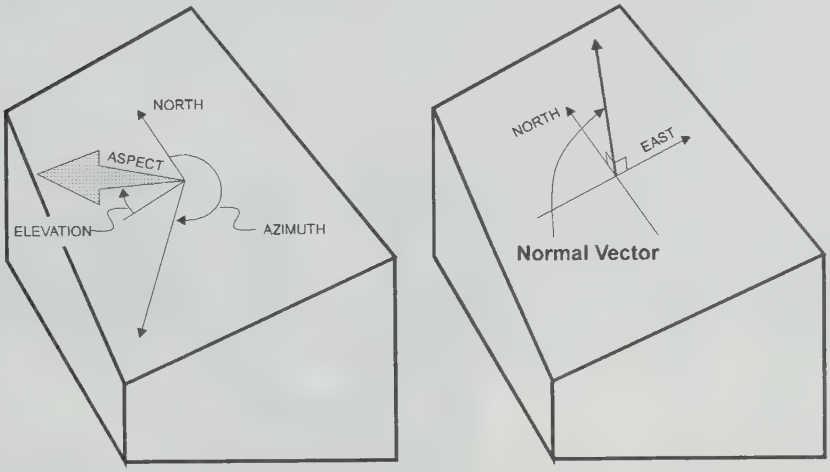
Buffering a line

e.g. All areas within
1 km to a road

Buffering an area

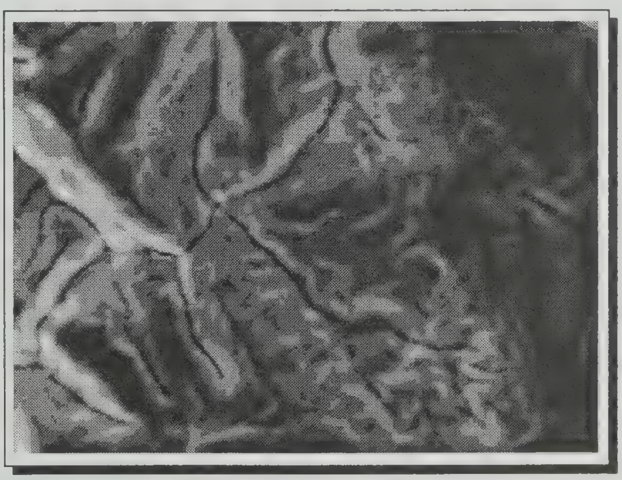
e.g. All areas within
500 metres of a building

Figure 6. Buffering



Source: Aronoff, S., 1989. Geographical Information Systems: A Management Perspective, WDL Publications, Ottawa.

Figure 7. Measurement of aspect. There are two components in the measurement of aspect. The horizontal angle or azimuth is the aspect direction. It is the angle formed by moving clockwise from north to the direction of the normal vector of the surface (i.e. the direction of the maximum slope). The vertical angle or elevation angle is measured from the horizontal to a line drawn perpendicular to the surface



Slope Magnitude of the Mt. Allan DEM The grey scale classes are between 0, 4, 10, 18, 28, 40, 54, 70, and 90 degrees scaled from black to white.

Figure 8. A example slope map generated from DTM (Courtesy of A.H. Evans)

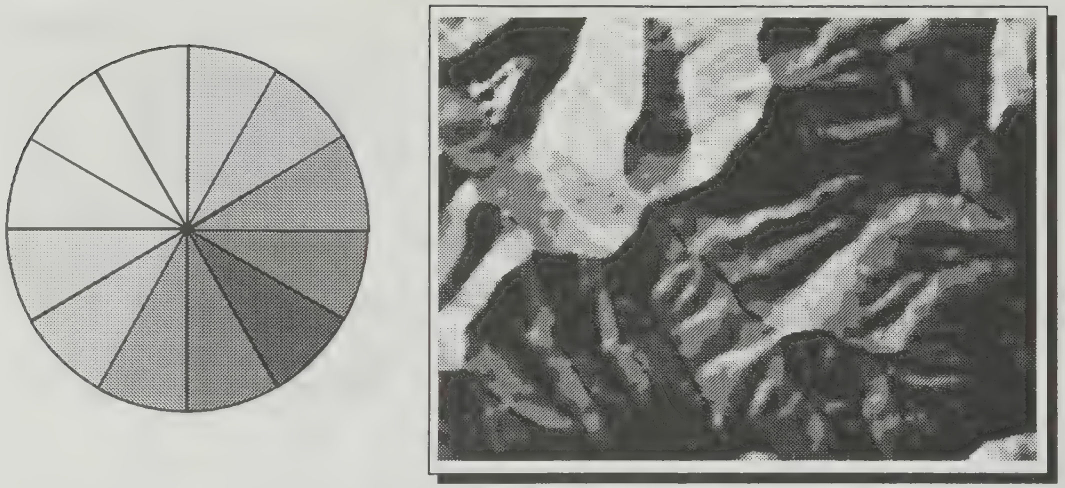


Figure 9. An example aspect map generated from DTM (Courtesy of A.H. Evans)

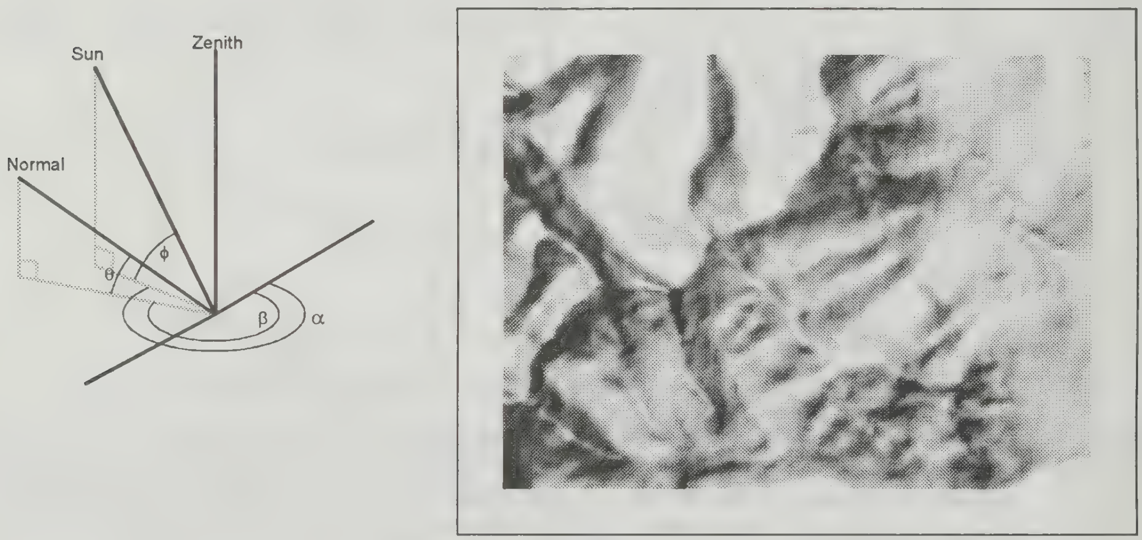


Figure 10. Relief shading using a DTM (Courtesy of A.H. Evans)

THE INTEGRATION OF GIS AND REMOTE SENSING FOR LAND RESOURCE AND ENVIRONMENT MANAGEMENT*

by

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ABSTRACT

The GIS has a continuing need for timely, accurate updates of the various spatial data elements held in its system and remote sensing system could, in many cases, benefit from access to highly accurate ancillary ground data which could significantly improve classification accuracy. Thus, there has been a continuous trend and an increasing demand for the integration of GIS and remote sensing, particularly in natural resources and environment management.

Both traditional GIS and remote sensing systems have limitations to integrate geo-based information and remotely sensed data. From the integration point of view, the traditional vector-based GIS fails mainly owing to the incompatibility problems in data structure and data processing; whilst the remote sensing image processing system fails mainly because of the capability limitations in handling geographical information. A likely solution lies in the concept of Integrated GIS which has been in the forefront of GIS research in the last decade.

1.0 Introduction

Geographic information systems (GIS) and remote sensing are well-established information technologies, whose value in applications in land and natural resources management are now widely recognised. They are, however, still essentially separate technologies and practitioners still generally consider themselves primarily involved with one or the other. This is explicitly recognised in 'definitions of the fields', a concern with different sets of tools, problems, and procedures as well as separate professional identities and orientation in the scientific community. This notwithstanding, it is becoming increasingly apparent that remote sensing and GIS do not stand in isolation but are part of a larger entity concerned fundamentally with handling and analysing geographical data in which neither is dominant (Fisher and Lindenberg, 1989; Faust, *et al.*, 1991; Estes, 1992). As Ehlers *et al.* (1989) have argued, "the more or less separate GIS and remote sensing communities have to accept that both need each other (and) the integration of these technologies will inevitably lead to a synergistic approach to spatial data handling". Integration of the technologies *per se* is, however, still a long way off, even if it can be argued that it is necessary, and is hindered by technical, institutional, even educational limitations.

2.0 Why integrating GIS and remote sensing?

The increasing demand on GIS and remote sensing integration is largely because of the following reasons:

(a) The GIS has a continuing need for timely, accurate updates of the various spatial data elements held in its system and remote sensing systems can be a important data source for this update;

* Presented at United Nations ESCAP Workshop on Remote Sensing and GIS for Land and Marine Resources and Environment Management, 13-17 February, Suva, Fiji.

(b) Remotely sensed data is, in most cases, the only data source which may make a real-time information system possible;

(c) Remote sensing system could, in many cases, benefit from access to highly accurate, ancillary ground data which could significantly improve classification accuracy;

(d) In real-world applications, the frequently-updated remotely sensed information needs to be converted into a more useful form for the user to support real-time decision-making activities, and GIS technology can best serve this purpose.

Although the basic tasks of both GIS and remote sensing systems are oriented towards solving problems relating to the spatial occurrence of phenomena, the integration of these systems presents some difficulties.

3.0 Distinction between GIS and remote sensing

There is often a good deal of confusion over where the line is between the GIS and remote sensing techniques. It is attempting to define remote sensing as a data source technology, and GIS as a data processing technology. But Parker (1988) had argued "... a better distinction would be that remote sensing constitutes an *external* information source for *input* to a GIS... although remote sensing data can be an important source for a GIS, it is usually not the *primary* source".

The functional differences between the two systems can be summarised in terms of their aims, employed techniques and applications.

The aim of a GIS is to provide the user with highly processed final products which are usually the information for *decisions* by which land administrative activities should be guided. The 'meaningful' information is considered as essential in a GIS and should be initially input from data sources. In a remote sensing image processing system, on the other hand, the input is sets of raw spectral information which are considered meaningless from the point of view of traditional geography. The aim of a remote sensing image processing system is to transform such 'meaningless' data into a 'meaningful' information. Thus, input data in a GIS can be the output information produced from an image processing system.

The basis of data processing algorithms of a GIS is computerised traditional geographical theories. For example, commonly used digital elevation models (DEM) are based on the assumption that every known data point in the database represents a elevation sample point on the ground in the real world; and the algorithm used to generate a slope map follows the traditional geographical method which evaluates the elevation of sourounding points for each spatial location then computes the slope angle using the ratio of elevation differences and horizontal distance between the sample points. In a remote sensing image processing system, major approaches to data processing are heavily oriented towards mathematical and statistical data processing techniques, regardless of the actual geographical meaning of the results. Geographical phenomena in the real world have to be interpreted using mathematical and statistical procedures applied to the spectral data recorded by remote sensors.

Most GIS applications involve handling spatial data in a well-organised database for data retrieval, updating and transformation applications. In other words, the GIS applications are more or less database management-oriented. An image processing system, in contrast, concentrates on spatial variation enhancement and auto-classification operations therefore it is data transformation-oriented, and usually there are no database management capabilities within an image processing system.

4.0 Issues and problems in the integration

For all intent and purposes, the current state of integration of remote sensing and geographic information systems can best be described as *task oriented*. Cartographic data from GIS in various forms is increa-

singly used to enable better analysis and classification of image data, albeit often as an end in itself. There has also been growing awareness of the potential GIS offers for incorporating enhanced image data with geographical databases, especially for applicatoins directed at process dynamics and the detection and monitoring of spatial change. This becomes particularly important for problems in which real-time or frequently updated information is required for monitoring purposes as in rural land use analysis. A good example, is the monitoring of land resources for which up-to-date information about the state of land use and natural resources is crucial. For these kinds of applications however, it is now apparent that the simplistic linear model of the relationsip between remote sensing and GIS, in which the former merely feeds data to the latter, is insufficient. To fully exploit the potential of integrating remote sensing and geographic information systems, a more complex model based on the symbiosis of the two is more appropriate.

4.1 Remote sensing input to GIS

To date, there has been limited direct input of digital remotely sensed data, especially data obtained from space platforms, into GIS databases. The issues of appropriate scale for applications and resolution of remote sensors have been debated for years and it has become obvious that GIS which concentrate on small, complex areas cannot be properly served by most currently available orbital remote sensors. However, even where GIS exist with apparently adequate scales and resolution, orbital remotely sensed data has still not been used very often although the great potential of incorporating such data has been widely accepted.

Moreover, in GIS where remotely sensed data has been incorporated into the database, this data has been commonly used for presentation and display purposes, with or without geographical features defined by geo-based thematic data planes in the database. Very few GIS, particularly vector-based systems, can functionally handle the remotely sensed data in geographical modelling operations.

Four major categories of problems exist in linking GIS and remote sensing, namely: *data characterisation, data structure, data processing* and *output approaches*. In fact, all these problems are conceptual rather than technical and, among them, the first two are the fundamental issues, out of which the latter emerge.

4.1.1 Data characterisation

For a GIS, 'data' has been considered as a type of 'information' which represents some spatial phenomena in the real world. In other words, if the term 'data' is considered as that representing the input to the system, then all the data must relate to some *real* geographical characteristics of the land. Examples of such characteristics could be townships, roads, landforms, population, drainage networks, and so on, which are spatially represented in the forms of points, lines, polygons and networks. For remote sensing, on the other hand, the terms 'data' and 'information' are considered as completely different terms, where the term 'data' denotes the input phase which is not necessarily a geographical feature, while the term 'information' denotes the output phase which should represent some geographical phenomena. In other words, from various types of remotely sensed spectral data, the system produces information by employing restoration, enhancement and information extraction techniques. It is clear that the information in the forms of points, lines and polygons describing geographical characteristics is a highly processed final product from remote sensing. Thus, the highly processed information produced from remote sensing system could be regarded as the raw input data to a GIS. Due to the difference in viewpoints, limited work has been done in the transformaiton of such data into the form acceptable by the other. This results in a conceptual 'data gap' which has been a critical barrier to link the systems.

For example, classified remotely sensed data has always been considered by GIS operators as one which provides only low spatial resolution and inadequate accuracy, compared to the vector spatial entities derived from other sources. Since digital remotely sensed data are "true statistical surface" (Berry, 1987b)

and most image processing operations are based on probability analysis of spectral data, the best results from information extraction techniques such as a multispectral classification often contains errors which may be well evaluated by statistical estimations. Majority GIS users, on the other hand, often argue that all input information must be in a highly generalised level such as thematic maps or a highly accurate vector measurement such as control points of land surveying, very few traditional GIS operations can readily handle probability estimations for error evaluation. Remotely sensed information, therefore, is nearly always rejected from geographical modelling procedures.

At least three issues need to be resolved in data characterisation before increased use of remotely sensed data can be anticipated in operational GIS:

(a) Data processing procedures need to be developed to transform the remotely sensed data into an acceptable form by the GIS.

(b) The spatial positioning of the remotely sensed data must be made acceptable in terms of the positional accuracy of the other data elements contained in the GIS.

(c) The accuracy of the classification scheme used must be such that the remotely sensed data can be treated on the same basis as other data elements in the GIS.

4.1.2 Data structure

One major obstacle to linking operational GIS with remote sensing systems is the incompatibility between the vector-based data structure employed by most GIS and the raster-based imagery of remote sensing. Although today's GIS can support both vector and raster data structures, the 'primary' approach towards spatial data encoding is most likely a vector data structure, since the structure follows traditional concepts of cartography and digital files which are created through digitisation operations and they can be directly accepted by the system. On the other hand, all remote sensing image processing systems employ raster data structure which is fully compatible with the raw data from remote sensors. Data incompatibility, therefore, is an obvious issue which needs to be resolved before any data transformation between the two systems can be achieved.

Although technically there is no real problem in converting a classified, pixel-based, digital remote sensing scene into a set of homogeneous polygons defined in vector data structure, the rather conceptual problems exist in the integration of the classified images and data from other sources. A vector-based GIS expects highly generalised information as its spatial data input, such as thematic maps in which all the internal variances within each map unit are ignored. The remote sensing image processing systems, unfortunately, rarely produce such information. Instead, a classified image from the image peocessing systems may contain too many sparsely distributed small polygons ensuring that the image can never be reasonably used in a geographical model in the GIS.

4.1.3 Data processing

The differences in data characterisation and data structures not only cause problems in data compatibility, but also problems in data processing. Data processing methodologies in any spatial data handling systems are dependent upon the data structures used in these systems. Data models need to be constructed and basic assumptions made that correspond to the data structure employed by the system.

In general, models used in a vector-based system describe a non-continuous data surface. Spatial data is recorded in such a manner that all variables within a polygon are assumed to be homogeneous. There are definite attribute changes in these variables at the boundary of the polygon. Data models in a raster-based remote sensing system, on the other hand, describe a continuous data surface on which each pixel in an image can be treated as a sample point and changes between these sample points are assumed to be continuous.

Using different data models, the vector-based data processing methods employed in GIS are based on *polygon*-oriented algorithms (Aronson and Morehouse, 1984; Green, *et al.*, 1985), whilst the algorithms used in remote sensing are *pixel* oriented. The difference of the two categories of algorithms gives rise to problems not only in data structure, but also in all data processing algorithms. Generally, the polygon-oriented algorithms tend to follow the conventional methods of traditional cartography, such as line intersection, polygon aggregation and disaggregation, topological overlay and buffering. The pixel-oriented algorithms, on the other hand, treat input data as Boolean surfaces and tend to perform Boolean, mathematical or statistical operations on the pixel-by-pixel basis.

The two sets of algorithms are not directly compatible and data have to be converted if they need to be processed and transferred from one type of algorithms to another. This causes a critical problem — that the output from one type of algorithms is not necessarily acceptable for the other! For example, Vegetation Indices (VI) are common products from the remote sensing pixel-based algorithms and considered to be very useful for environmental management. These data, however, are hardly accepted by any vector-based GIS simply because the polygon oriented algorithms do not accept the vast number of sparsely distributed small polygons that are converted from a original VI image; while the data might be completely useless in many applications if an over-generalisation has been applied to decrease number of polygons to a reasonable number for handling.

4.1.4 Output approaches

Most operational GIS utilise the 'cartographic' output approach to produce map products which are in form similar to analogue maps. Retrieved vector data can be presented by lookup tables which define colours, patterns, labels and so on, through a 'graphic pipeline' (Foley and Van Dam, 1982; Hearn and Baker, 1986) to the hardware display unit. Remote sensing systems, on the other hand, utilise the 'photographic' approach to produce image products. Image data can be presented through a 'colour composite' (Sabins, 1978; Jensen, 1986) based on the brightness value of each band of the remotely sensed data. This sort of image display is not always accepted by the primary GIS users, and it is often difficult and inefficient to display this type of output using vector-oriented display devices.

4.2 Geo-based information input to remote sensing

An alternative approach to input remotely sensed data into GIS is to direct the data flow in the opposite direction, i.e., from the GIS to the remote sensing image processing system. This approach has been debated by remote sensing researchers as the techniques of introducing so-called 'ancillary' data into image processing.

One approach arising from these developments is to introduce geographical information such as elevation, slope, aspect, soil, vegetation into image processing processes to improve the accuracy of classification. Some 'pure' image processing techniques have been developed for incorporating such ancillary data. For example, Richards, *et al.* (1982) and Swain, *et al.* (1985) developed a technique based on *label relaxation* methods by which a spectrally determined classification map could be modified to account for spatial relationships of cover types within pixels in a local neighbourhood Strahler, *et al.* (1978) described two methods of incorporating topographic information into the classification procedure. The first, termed the 'logical channel' approach, treated the topographic information logically as additional Landsat spectral channels in the context of a conventional multivariate classification framework. The second method, termed the 'probabilistic' approach, also employed spectral channels, but used the topographic information to modify prior probabilities of class membership in maximum likelihood decision rules employed in the classifier. Franklin (1987) introduced a method that used the geomorphometric system of terrain descriptors to augment the accuracy with which terrain classification in the landscape approach can be done using surrogate multispectral images.

Another approach is to use the remote sensing image processing system as a tool box and perform some Boolean data processing based on some geographical models. For example, Spanner, *et al.* (1983)

processed geographical information including slope, climate and soil together with a classified Landsat MSS imagery representing vegetation types, to predict soil erosion using a soil erosion model named *Universal Siol Loss Equation* (USLE) (Wischmeier and Smith, 1965). This is a geographical modelling rather than a pure image processing and has been called data processing using 'a geographic information system format' by Spanner, *et al.* (1983). Cibula and Nyquist (1987) employed similar method to incorporate topographic data and watershed boundaries data with the Landsat MSS data to derive vegetation/landcover classes using Boolean operations.

The results of these studies have been encouraging. Richards, *et al.* (1982) and Strahler, *et al.* (1978) claimed that overall accuracy of the classification in forest applications could be improved from 68 per cent and 55 per cent and 85 per cent, respectively. Franklin (1987) claimed that the classification accuracy increased from 46 per cent to 75 per cent in a high relief environment through the introduction of ancillary data such as elevation, slope, incidence, relief and convexity in the image enhancement/classification process. Spanner, *et al.* (1983) also claimed that 84 per cent of the pixels were correctly classified in their soil loss prediction. Cibula and Nyquist (1987) reported that a high level of accuracy was maintained while the number of land-cover groups was increased from 9 to 21.

However, at least four problems exist which prevent further applications in linking GIS and remote sensing:

(a) The complexities of the GIS environment have been poorly understood by remote sensing analysts and systems optimised for remote sensing data processing often have limited GIS capabilities;

(b) The lack of a Data Base Management System (DBMS) causes severe problems of data redundancy and inconsistency. This also makes attribute data manipulation such as relational retrieval and update extremely difficult within an image processing system environment;

(c) Typical remote sensing systems do not have the capability to handle data obtained at low levels of measurement. For example, it is very difficult, if not impossible, to handle non-numerical information using an image processing system;

(d) Traditional image processing systems do not support geographical modelling operations, for example, digital terrain models, landform analysis, potential zone analysis.

5.0 Integrated GIS

Modern GIS development has been largely oriented towards the concepts of integrated GIS which are designed to cope with spatial and attribute data from various sources with different data structure. The fundamental capability of such integrated system is to be able to present spatial information to the user in a 'transparent' manner regardless whatever the original data format is. Ehlers, *et al.* (1989) summarised the evolution of Integrated GIS as below:

Stage 1: Two separate software packages running in tandem.

Stage 2: Two software packages running in tandem, linked interactively or by import/export modules.

Stage 3: Two software modules with a common user interface.

Stage 4: One software unit with combined processing.

5.1 Image-based GIS

One popular simple solution towards integrated GIS is image-based GIS (IGIS) which employ a raster data structure, incorporates remote sensing data, and have data interfaces to vector-based data. An IGIS has three basic characteristics which distinguish it from other systems. Firstly, the IGIS is a GIS, and

not a remote sensing image processing system, hence it should have the necessary geographical data handling capabilities. Secondly, the IGIS is raster-based and therefore fully compatible with remote sensing images and data processing employing raster algorithms. Thirdly, the IGIS is equipped with effficient data interfaces for converting vector data from other GIS to a raster data structure, for transferring geographic information and remotely sensed data between the GIS and image processor and for displaying processing results by both cartographic and photographic manners. Within the IGIS environment, geographical information can be transferred to image processor and processed with remotely sensed data to improve classification accuracy; and both raw remotely sensed data and results of classification can also be transferred from image processor to the IGIS for more complicated geographical modelling processes using raster algorithms.

The concept for IGIS initially grew out of the Image Based Information System (IBIS) developed in the Jet Propulsion Laboratory (JPL) of the California Institute of Technology (Bryant and Zobrist, 1976, 1981). The IBIS, built upon an existing image processing system, the Video Image Communication and Retrieval system (VICAR), was however, very much image-processing oriented (Marble, 1980; Zobrist and Nagy, 1981), even though it did contain a number of powerful GIS capacilities.

Following the IBIS concept, other systems have been developed for a variety of application purposes (Graetz, *et al.*, 1982; Bartolucci, *et al.*, 1983; Ritter, *et al.*, 1984; Van Vuuren, *et al.*, (1986). These systems also emphasised image processing techniques, but incorporated some GIS operations and have interfaces to vector data sets. Alternatively, raster-based modelling systems have also been developed based on more traditional geographical spatial modelling techniques (Tomlin, 1983; Olsson, 1985) and attempts have been made to define and implement fundamental operations in IGIS to provide coherent and flexible support for a range of applications (Berry and Tomlin, 1982; Tomlin, 1983; Berry, 1987a, 1987b). The modelling systems emphasised spatial modelling applications using 'social physics' (Olsson, 1985) and 'cartographic modelling' (Tomlin, 1983, 1990) techniques and focused heavily on data transformation rather than database application operations.

Significant efforts have been made to develop techniques incorporating vector and raster geographic information (Maffini, 1987). Logan and Bryant (1987) reported a research in linking the IBIS with a CAD/CAM system. With this linkage, vector thematic information can be captured by the CAD/CAM system and then manipulated in the IBIS, while raster data can be converted into vectors which can then be output through the CAD/CAM system. Tabular data which records attribute information of its corresponding spatial data entities are stored in a form called 'interface file' and can then be used for producing a thematic map by both IBIS and the CAD/CAM system. A further development was also reported by Zhou (1989) by incorporating Relational Data Base Management System (RDBMS) techniques into the IGIS environment.

5.2 Task-oriented integration

Although the integrated GIS has been a continuous focus of GIS technology development, most applications to date can best be described as taking 'task oriented' approach in which data exchange between GIS and remote sensing system is focused, rather than developing a fully integrated system. This approach provides easy solutions towards application problems using existing software systems and therefore has been adopted in many GIS projects which require remote sensing input.

The critical techniques employed in this task-oriented integration is the design and implementation of application models which incorporated both GIS and remotely sensed data. This commonly employs 'cartographic modelling' techniques (Tomlin, 1990) and data exchange facilities which can easily be found in many today's GIS packages. In such an approach, the key to successful spatial modelling is to get the correct scientific theory behind the models. These models are usually the results of scientific studies which are in most cases beyond the domain of GIS technology. It is important to understand that GIS does *not* create a model — it can only *implement* a model, based on a theory, in a spatial information context so as to assist decision-making process — the ultimate goal of GIS technology.

6.0 Case study: Physical planning in tweed region, NSW Australia

To illustrate the task oriented approach towards an integrated GIS application, a case study project has been undertaken in Tweed region at northern New South Wales — one of the most rapidly developing region in Australia. The purpose of this project is to produce a regional development plan which is environmentally sound and capable of delivering the maximum economic benefit to the region.

6.1 Problems to be addressed

A number of tasks have been identified to achieve the goal of the project. These include:

(a) Land resource inventory which is fundamentally based on FAO land capability assessment;

(b) Evaluating land suitability to selected economic activities which have been identified as major factors on demand of land resources; and

(c) Selecting the optimal highway path through the region.

The project is largely built on a foundation of a series of scientific and technological studies in the region, including soil, land suitability and remote sensing studies.

6.3 Land resource inventory

Located in the south fringe of Australia tropical area, the Tweed region is experiencing its early stage of rapid economic growth owing to the large impact of agriculture activities, housing and urban development and tourism development. To address dramatic increasing demands on the land resources and frequent conflict of different interest groups, it is essential to conduct a comprehensive land resource inventory and classify the land resource according to its capability and limitations for land use.

The land capability mapping was therefore undertaken based on existing thematic maps including soil, topography and geology, climatic data FAO land capability assessment methodology.

Factors under consideration are slope, occurrence of acid sulphate soil (ASS) or potential acid sulphate soil (PASS), water logging, soil texture, depth, fertility and erosion risk, and frost risk. The land capability classification based on these factors is listed in Table 1.

Table 1. Land capability classification for Tweed Region, northern New South Wales

Class	Slope	Texture	Depth	ASS	Logging	Erosion	Frost	Fertility
I	0-1	Loam	> 100	No	No	Low	0	High
II	2-5	Clayey or sandy loam	50-100	Yes	Occasional	Low	1-5	Medium
III	5-15	Silty clay loamy sand	50-100	Yes	Frequent	Medium	5-20	Medium
IV	15-25	Silty clay loamy sand	30-50	Yes	V. Frequent	Medium	> 20	Low
V	25-33	Silty clay loamy sand	30-50	Yes	V. Frequent	Severe	> 20	Low
VI	25-33	Silty clay loamy sand	20-30	Yes	V. Frequent	Severe	> 20	Low
VII	25-33	Silty clay loamy sand	20-30	Yes	V. Frequent	Severe	> 20	Low
VIII	> 33	Massive pure sand	< 20	Yes	Swamp	V. Severe	–	–

Based on this classification system, a land capability model has been created and implemented in ARC/INFO GIS software system using its raster-based GRID software module. The input data layers include digital contour data, soil and geology maps which are recorded in a vector format and climatic data recorded in a tabular format. These data were then converted into raster format in order to be incorporated into the land capability model which can best be implemented in a raster GIS. The computational model can be illustrated in Figure 1.

6.3 Land suitability evaluation

Based on land resource inventory and existing land use and land zoning, land suitability for selected economic activities has been evaluated for each location of the region. Current land use information was acquired using existing land use map and updated using SPOT imagery and existing land zoning was digitised from council planning map.

The selected economic activities include tourism, horticulture, coffee cropping, pasture, housing development and sugarcane cropping. Interviews were conducted with experts in agriculture, town planning and tourism, and people from different interest groups. Criteria were then selected against each economic activity according to its demand on land resources and impact to the environment. The results were then implemented in a GIS model which can then be executed to produce a land suitability map for each selected activity. These suitability maps can later be overlapped to identify the conflict area on land demand and maximum economic benefit in using land resources can then be analysed.

To demonstrate the methodology, land suitability evaluation for coffee cropping is outlined here. It is important to understand that the coffee model demonstrated here is a largely simplified model for demonstration and designed for Tweed area only, therefore it is not necessarily applicable elsewhere.

6.3.1 Example: Suitability for coffee cropping

Australia has not been a traditional coffee producing country although it covers a large humid tropical area which can potentially be used for coffee cropping. This is largely because coffee cropping requires an extensive labour input for hand picking during the harvest and economic constraints that are mainly controlled by the high Australian labour cost. Recently, machine picking technology has been invented to substitute the expensive hand picking and a dramatic reduction of world coffee productivity was experienced owing to the recent frost disaster in Brazil. Coffee cropping has started to be considered as a profitable activity in Australia.

At the south fringe of the Australian tropical area, the local conditions for coffee growing is critical and vary from place to place. Experiments were conducted in Tweed region and conditions suitable for coffee cropping has been identified by the NSW Department of Agriculture.

Based on these agricultural studies, simplified natural and infrastructural conditions for coffee cropping were summarised as:

- Slope must be within the range from 5 to 15 degrees to suit machine picking;
- The land must have a northwest aspect to minimise the frost risk;
- Frost days must be less than 5 days per year;
- Soil texture must be in the range from loamy clay to sandy loam;
- Soil fertility must be medium or better;
- The land must not have water logging risk;
- Accessibility to the nearest road must be less than 2 km for transportation.

Based on these criteria, a coffee suitability model has been created and implemented in GIS. The input data sets include slope and aspect derived from an digital elevation model which was created from the digital contour data, soil map, records from weather stations in and surrounding the study area and

road network created from topographic maps and updated using SPOT imagery. The coffee suitability model is illustrated in Figure 2.

6.4 Selecting optimal highway path

Based on the results of land inventory and land suitability studies, an analysis was also conducted to assess a proposed highway bypass project by Road and Traffic Authority (RTA) which tried to ease traffic across the region. This project, however, has drawn some significant controversy as the proposed route will cross large areas of marine lowlands resulting in potential natural disasters in the Tweed River system caused by oxidation of underlaid acid sulphate soils.

The project therefore has conducted an analysis on the solution of an optimal route for the bypass project which will consider the cost of development including land acquisition and engineering costs and minimising potential environmental impact such as acid flow risks caused by ASS oxidation, deforestation, soil erosion and impact on natural habitat and tourism resources. As a result, an optimal highway path model has been developed and implemented in GIS and a optimal highway pass map has been produced for preliminary planning consideration.

Figure 3 demonstrates the GIS model which evaluated the cost of development for the highway project.

6.5 Optimal highway path model

7.0 Conclusion

GIS, when integrated with remote sensing, makes it possible for a real-time resource and environment management system. This integration will best benefit change detection, resource monitoring and environment modelling.

Remotely sensed data become much more useful when they are integrated into decision support system with GIS. Spatial data from GIS will provide significant benefit for remote sensing image processing by proposing map-guided stratification, enhancing accuracy and efficiency of auto-classification, and conducting post-classifier sorting.

Issues and problems exist and there are also some limits yet to be improved with the progress of the technology.

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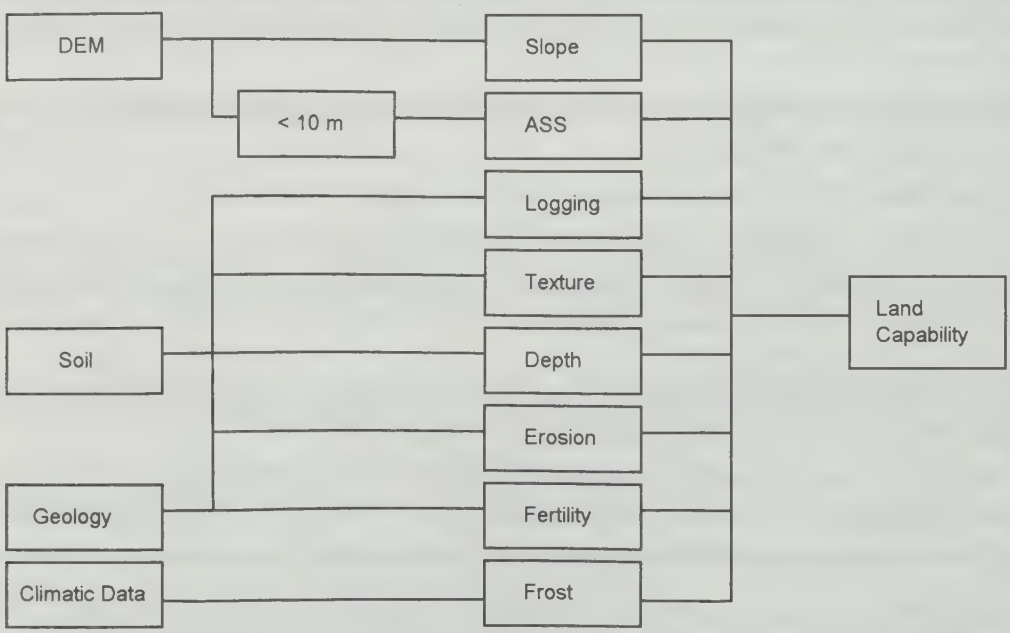

Figure 1. Land capability model for Tweed Region, northern New South Wales

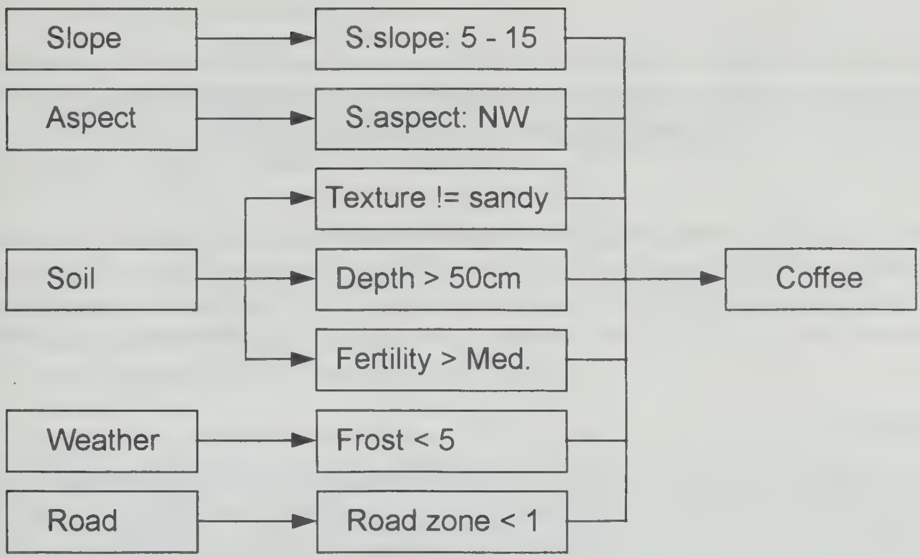

Figure 2. Coffee suitability model for Tweed Region, northern New South Wales

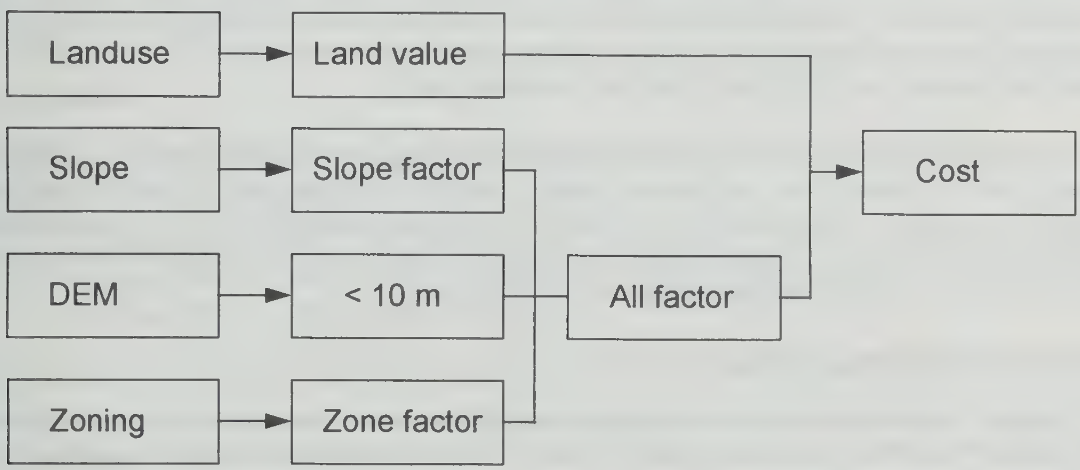

Figure 3. Cost model for the optimal highway path cross Tweed Region, northern New South Wales

REMOTE SENSING: AN INTRODUCTION AND SOUTH PACIFIC APPLICATIONS*

by

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1.0 Introduction

Remote sensing is the science and art of obtaining information about an object, area or phenomenon from data acquired by a device not in contact with the target under investigation. However it is not a magic technique which can solve any problem. It is, instead, a "tool" which, properly used in conjunction with the other traditional survey techniques, greatly improves our knowledge of the earth.

The utility of aerial photographs has long been recognised. With the advent of instruments recording electromagnetic radiation beyond the sensitivity range of the human eye and cameras, man's "vision" has been greatly extended. Although distinctions are made between classic photo-interpretation and non-photographic remote sensing, remote sensing as defined generally includes photographs, non-photographic imagery (for example, satellite digital data) and numerical data.

Ground observation has by no means been superseded by remote sensing. However, collection of data on ground is relatively slow and tedious, whereas remotely-sensed data can be utilised easily by an experienced interpreter. The interpreter can obtain a more comprehensive record of an area than could be obtained on the ground. In addition remotely-sensed data can provide information on earth resource features that cannot be obtained practically by any other means.

2.0 The remote sensing system

A remote sensing system which utilises electromagnetic radiation has four components: a source of electromagnetic radiation, interactions with the Earth's surface, interaction with the atmosphere and a sensor to record reflected radiation:

1. *Source.* The source of electromagnetic radiation may be natural (either the sun's reflected light or the earth's emitted radiation) or man-made. Sensors utilising natural radiation are termed "passive", while "active" sensors produce their own radiation. Passive sensors can not acquire data when it is cloudy, and those sensors dependant on the sun's energy to illuminate the earth's surface can not be used at night. Active sensors can acquire data regardless of the time of day and weather conditions. An example of an active sensor is microwave radar.

2. *Earth's surface interaction.* The amount and characteristics of radiation emitted or reflected is dependent upon the characteristics of objects on the earth's surface.

3. *Atmosphere interaction.* Electromagnetic energy passing through the atmosphere is distorted and scattered. For quantitative remote sensing studies, the atmospheric effects must be accounted for.

4. *Sensor.* A sensor, for example a camera or a radiometer, records the reflected electromagnetic radiation that has interacted with the surface of the earth and the atmosphere.

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* United Nations Remote Sensing/GIS Workshop for Land and Marine Resources and Environmental Management in the Pacific Subregion.

3.0 The electromagnetic spectrum

Remote sensing utilises radiation to measure physical parameters of surfaces and to give images from radiation within and beyond the range of the human eye sensitivity. The electromagnetic spectrum includes all frequencies (and therefore wavelengths) of electromagnetic energy. The visible part is a very small portion of the whole spectrum.

The shortest wavelengths usually employed in remote sensing range around 300-400 nanometers (nm), where 1 nm = 10^{-3} micrometres (μm) or 10^{-6} metres. This is because of high atmospheric scattering in wavelengths greater than 400 nm. The most popular regions are the visible, the infrared and the microwave. The visible part of the spectrum ranges from 400-700 nm. Remote sensing instruments such as multispectral scanners split this into several distinct bands.

The infrared part of the spectrum (from $700\text{-}2^*10^4$ nm) is subdivided into the near infrared (often called photographic- or reflected-infrared) from $700\text{-}1.1^*10^3$ nm, and the thermal infrared bands (from $3^*10^3\text{-}5^*10^3$ nm and $8^*10^3\text{-}14^*10^3$ nm). The near infrared involves energy coming from the sun and reflected by earth surfaces, compared to the thermal infrared which involves energy emitted from surfaces which is related to their temperature.

Microwave sensors operate between the wavelengths of approximately 1 mm and 1 m. Microwave sensing devices can be used in both active and passive systems. Passive microwave sensors use the natural radio emission of the earth and the effects on it of earth and atmosphere constituents to sense a variety of geophysical parameters.

4.0 Platforms

The most appropriate platform depends on the particular investigation. The frequently used platforms include:

1. *Ground systems* which permit collection of "ground truth". These involve either ground-based measurement of electromagnetic radiation, or field observations, useful for the calibration of the data collected from aircraft or satellite.
2. *Aircraft* which permit mapping of small areas from imagery with a very high spatial resolution.
3. *Satellites* which permit mapping of large areas in a quantitative and repetitive manner (providing a synoptic view of the earth). The spatial resolution of the imagery is low but for many activities the resolution is adequate.

5.0 Resolution

Resolution, or resolving power is, in general, a characteristic of the sensor or the survey instrument, but this parameter is normally related to the imagery. It is possible to define resolution as the smallest meaningful element detectable from the background.

5.1 Spatial (or ground) resolution

In the case of scanners spatial resolution is a function of the IFOV (Instantaneous Field of View). The resolution element is called "pixel" (from picture element), and the value of the pixel is the average of all reflectances within the IFOV. For scanners mounted in aircraft the IFOV normally ranges from 1-2.5 milliradiands (mrad). From 1,000 m altitude, this would achieve a ground resolution of 1-2.5 m. A satellite scanner with an IFOV of 0.020 mrad, orbiting at an altitude of 1,000 km achieves a ground resolution of 20 m.

In the case of photographic sensors the spatial resolution depends on the physical characteristics of the film used, the focal length of the optics (or the survey scale) and the distance from the object. For

example, a good photographic film can discriminate 80 or 100 lines per mm. Therefore if the photo is taken on a scale of 1:10,000, the resolution can range from 12.5-10 cm on the ground.

5.2 Spectral resolution

Remote sensing sensors are normally multispectral or multi-band systems. This means that they record several images of the same scene, in different spectral bands. For example, the Landsat satellites are equipped with a sensor called MSS (Multispectral Scanner) which collects energy and produces images of the same scene in four bands simultaneously, i.e. Band 4 (500-600 nm), Band 5 (600-700 nm), Band 6 (700-800 nm), and Band 7 (800-1,100 nm). For Bands 4,5,6 the spectral resolution is 100 nm, while for Band 7 the spectral resolution is 300 nm.

5.3 Radiometric resolution

Radiometric resolution is defined as the smallest amount of energy that can be detected by the sensor.

5.4 Temporal resolution

Temporal resolution is the elapsed time between two surveys of the same site. As it is often important to monitor changes of natural resources (for example, forest logging, soil erosion), it is necessary to survey the relevant study site repetitively.

6.0 Spectral signature

The sun illuminates the earth's surface with white light, which contains all wavelengths of the visible spectrum. Coloured objects reflect only light of particular wavelengths and absorb all other wavelengths of the spectrum. It is possible to draw a graph where, for a given object, the various reflectances in each wavelength are plotted. This graph is the object's spectral signature. The identification of an object by the remote sensing of its spectral reflectance is a most difficult problem in remote sensing. Such an identification method requires groundtruth, in order to calibrate the remotely sensed images to determine the relationship between an object and its reflectance. Spectral signatures are strongly influenced by the season of the year and the geographical location of the area. It is practically impossible to transfer the results from one country to another or to consider the spectral signatures as being valid for all periods of the year within a country or region.

7.0 Film types used for aerial photography

Photographic film is sensitive to electromagnetic radiation within the range 400-950 nm. The 400-700 nm range is visible (blue, green and red) light. The spectral range between 700-950 nm is that part of the reflected infrared region to which photographic film is sensitive. Compared to non-photographic sensors, the spectral range recorded by photography is quite narrow.

7.1 Black-and-white films

Black-and-white aerial photographs are normally recorded on either panchromatic film or black-and-white infrared film. Panchromatic film (sensitive to visible light only) has been the conventional film type for aerial photography. For both film types ground features appear as grey tones on photographic prints. However, the same features can have quite different grey tones on prints from these two film types. For example, on black-and-white infrared prints, streams and drainage channels have a dark (almost black) grey tone contrasting with lighter toned pasture areas; on the panchromatic prints, streams and drainage channels have a light grey tone, somewhat similar to the light grey toned pasture areas.

7.2 Colour films

Colour films are composed of three dye layers, each being sensitive to reflected radiation of a particular group of wavelengths. Normal colour films, which can be processed to either a negative or a positive, are sensitive to visible light and, when correctly processed and printed, features appear in their natural colours. Colour infrared film is sensitive to both visible light and near infrared reflected radiation. This colour film is exposed through a yellow filter (which does not transmit blue light) enabling green, red and near infrared radiation to each expose a separate dye layer. Red print colours result from near infrared reflection, green colours result from red light reflection and blue colours from green light reflection. Because of this unnatural colour rendition, this film type is often referred to as false colour infrared.

Colour infrared film is useful for vegetation surveys because it shows, more clearly than either black-and-white or natural colour film, the condition of vegetation cover. It has this capability because a plant's infrared reflectance is highly sensitive to physiological stress, i.e., the more vigorous the plant, the more near infrared radiation it reflects. Normal colour film does not show vegetation condition as well as does colour infrared, but is as useful for differentiating vegetation types.

Of the film types discussed above, no one type is best for recognising all features. Colour film types, however, provide an interpreter with more information because the human eye can recognise a far greater range of colours than of grey tones.

8.0 Airborne video

Video technology has been used for many years by public broadcasting services, however it has only recently become available in a form suitable for use by the remote sensing community. The main features of airborne video are:

- Real-time display of acquired imagery, allowing resource management decisions to be made very soon after the imagery has been acquired;
- Very low acquisition costs;
- Easy conversion of imagery to digital form, permitting computer-based analysis of data;
- Wide sensitivity of image tubes and CCD arrays — to both low light and extended spectral response. This permits airborne video to be acquired in poor weather conditions.

Airborne video is ideally suited to data acquisition for infrequent climatic phenomena and disaster situations because of its real time access, sensitivity to limited amounts of energy and it can be used under demanding weather conditions (Carr and Stephens 1986). Despite the disadvantages of its low resolution, low swath width (in relation to resolution) and uncertainties in calibration, airborne video is being used for an increasing range of applications. These include a range of diverse applications from ecological work in arid rangelands (Pickup *et al.* 1994) to mapping and monitoring forest health problems (Hosking *et al.* 1992).

9.0 Airborne scanner

Scanners in aircraft are typically used to provide increased spatial and spectral resolution relative to satellite-borne scanners. Airborne scanning instruments can have up to 288 channels of very narrow bandwidth (2.6 nm) data. Further, airborne scanning offers greater flexibility in controlling imaging missions in terms of acquiring imagery within time and location constraints. In addition scanners can have roll, pitch and yaw stabilisation to reduce the problems associated with data rectification.

10.0 Satellite remote sensing

It is recognised widely that satellite remote sensing can provide an inexpensive, rapid and effective method of data collection and production of small of medium scale (1:100,000-1:50,000) thematic maps. Furthermore, remote sensing provides an opportunity to view and assess natural resources in inaccessible areas at any season of the year, at low cost. A description of the currently orbiting satellite sensors recording in the visible and infrared portions of the spectrum is given in Table 1.

Table 1. Visible and infrared satellite sensing systems providing data to the South Pacific

Satellite: Sensor	Channels	Pixel size (m)	Swath width (km)	Repeat cycle	Lifetime
NOAA:					
AVHRR	580-680 nm	1,000	2,700	2 per day for two satellites	1978-present
	725-1,100 nm				
	3.55-3.93 μm				
	10.5-11.3 μm				
(NOAA 9, 10, 11)	11.5-12.5 μm				
Landsat:					
Landsats 1, 2, 3				18 days	
Landsats 4, 5				16 days	
Multispectral (MSS)	500-600 nm	80	185		1972-1993
	600-700 nm				
	700-800 nm				
	800-1,100 nm				
Thematic Mapper (TM)	450-520 nm	30	185		1983-1993
	520-600 nm				
	630-690 nm				
	769-900 nm				
	1.55-1.75 μm				
	2.08-2.35 μm				
	10.4-12.6 μm	120			
SPOT:					
Multispectral (XS)	500-590 nm	20	60 x 2	26 days (with off-nadir on request)	1986-present
	610-680 nm				
	790-890 nm				
Panchromatic (PA)	510-730 nm	10	60 x 2		

The main factors which make satellite data valuable in natural resources surveys and monitoring are the:

- Synoptic view of earth resources satellites, encompassing areas measuring thousands of square kilometres;
- Frequent repetitive coverage which enables discrimination of subtle seasonal changes;
- Availability of data collected in selected portions (or bands) of the electromagnetic spectrum;
- Possibility of analysing these data both digitally and by analogue methods.

When used in conjunction with interpretation of aerial photographs for detailed study it is usually possible to achieve results accurate enough to be transferred to medium scale topographic maps (i.e. 1:50,000-1:25,000).

11.0 Integration of remote sensing and geographic information systems for natural resource management

Natural resources management requires:

- Adequate information on economic, biological and physical resources;

- Knowledge on current socio-economic, biological and physical constraints and future potential;
- Predictions of future scenarios.

However the large quantities of data involved, differences in data formats, and the difficulty of integrating datasets from various disciplines, make it difficult to determine the viability of a particular resource use and to make predictions about future trends. Computerised information systems can reduce these data management problems. The integration of remote sensing and geographic information systems (GIS) provides a computerised information system which has considerable potential for natural resource management, where the benefits are:

1. *Cost effective routine updating of GIS data.* As much of the input data upon which a GIS is based often becomes obsolete quickly, it is essential to update this data periodically. Use of remote sensing techniques is often the most cost effective updating procedure.

2. *Improved accuracy of computer assisted techniques for information extraction from digital images.* This can be accomplished by incorporating appropriate GIS data layers into the analysis. For example, the accuracy of vegetation mapping using remotely sensed data has been improved by incorporating ancillary data such as slope, aspect, elevation and climate parameters. Such ancillary information is used by the image analyst to segment and label digital images prior to using image classification algorithms.

3. *Inclusion of digital images as maps.* Digital images (obtained from either digitised aerial photographs or digital sensors) can be used as a digital photomap in a GIS. This provides an excellent base map upon which other GIS layers of data can be overplotted enabling spatial variations (in the GIS data) to be observed.

4. *Prediction of future scenarios.* Computerised information systems have the potential for modelling future scenarios of resource availability and condition. The futures situations can be based either on the continuation of current trends or influenced by interventions through administrative policy change.

12.0 Appropriateness of spatial information systems

Efficiently operating a spatial information system comprising remote sensing and GIS components is not a straightforward task. This is true in particular for agencies in the South Pacific region that have limited experience with these technologies (Stephens 1991). Significant problems can arise once a system has been purchased, installed and commissioned. The maintenance and efficient use of a spatial information system involves:

- Ready access to support for all hardware and software;
- A regular power supply;
- A source of spatial data, appropriate to the management problems at hand;
- A commitment by agency administration to fully finance and support the information system and to retain trained and experienced staff;
- Ease of communication with skilled people from outside agencies who are capable of assisting when problems arise.
- Skilled people who can support computer operations, are fully conversant with the software, understand the data types stored, relate to the problems of natural resource management and the environment, are involved in refresher courses and workshops appropriate to their work and are prepared to remain with an agency for at least two years.

Cognizance of these points as well as careful selection of hardware and software, the nature of the problem and the skill base of the users, should ensure an appropriate development path for integrated spatial information systems. This is fundamental to the applied use of remotely-sensed data.

13.0 Applicability and technology transfer

A proliferation of new technologies does not guarantee their application to natural resource management. The technical characteristics of sensors must be appropriate for the detection and mapping of the targets of interest. Even if the technical issues are resolved, attempts to apply the technology may still end in failure. Specter and Gayle (1990) discuss obstacles to the transference of remote sensing technology to development programmes, paramount obstacles being economic, political and social. Another issue hindering the technology transfer process is the lack of awareness, expertise and training of technical and managerial staff in user organisations.

To become an economical viable tool for natural resource management, remote sensing must generate products that are both needed and affordable. This requires that the tool be user-driven, and tailored to specific resource management problems (Huntington 1994, Green *et al.* 1994). Tailoring does not however necessarily mean complex data manipulation. For example, operational land use and vegetation mapping undertaken by the Swedish Space Corporation has been achieved by using manual methods of information extraction from remotely sensed satellite data, in preference to digital classification (Rosenholm 1993).

In their paper on use of AVHRR data for environmental monitoring, Ehrlich *et al.* (1994) attribute the paucity of applications to map landscape parameters to the cost of hardware and software for preprocessing. Scientists and managers outside the remote sensing community rarely possess the equipment and knowledge to process satellite data for use in their application. With the availability of standard AVHRR products such as the NDVI composites and the use of electronic networks to query data sources and to transfer data, more use will be made of remotely-sensed data by managers and scientists in the user community.

14.0 Which type of data to use?

A problem facing managers who have resource issues requiring more information is deciding whether remote sensing is an appropriate means of acquiring data and what type (or types) of remote sensing they should use. Given that remote sensing is regarded as being appropriate to provide data, the following should be considered before a data type is chosen:

- Availability and suitability of existing remotely-sensed data;
- The size of the area to be surveyed;
- The spatial and spectral characteristics of resources (for example, bare soil, turbid water) that need to be mapped or identified;
- The amount of time to have the survey completed;
- The frequency of data acquisitions;
- The amount of money available for data acquisition and data interpretation;
- The skill level of staff in interpreting data, and the hardware and software available;
- The methodology for analysing data, and the accuracy of the derived information;
- The format in which the information is required (statistics, images, maps, GIS coverages);
- The type of ground truth required to support interpretation of remotely-sensed data.

Once these points have been considered then it should be possible to decide on the most appropriate type of data to use for natural resource inventory and assessment purposes.

15.0 Applications of remotely-sensed data to Pacific land resources

Examples of using remotely-sensed data for management and monitoring of land resources related to the South Pacific include:

1. *Cyclone damage mapping.* Cyclone damage mapping has been undertaken using SPOT satellite data and GIS datasets, aerial photography, and airborne video singly or in combination.

   SPOT data have been used to determine the total area of bare ground, on a farm-by-farm basis (Trotter *et al.* 1989). The bare ground (comprising landslide scars and debris-tails) was caused by Cyclone Bola in New Zealand. However, the landslide scar and debris-tail components could not be resolved on the basis of radiance levels. These components were instead determined from representative landforms in the region by a combination of photo-interpretation and digitisation/classification of 1:5,000 scale colour aerial photographs which covered a small part of the affected region. An estimate of the average ratio of scar to debris-tail for an individual farm was then obtained by intersection of a regional landform map and a farm boundary overlay, using a GIS. In another study using SPOT data, Loubersac *et al.* (1988) used pre- and post-Cyclone Sally SPOT XS imagery to map cyclone impact in the Aitutaki Atoll. Changes mapped included sediment accumulation and vegetation damage.

   An aerial photographic reconnaissance survey of Cyclone Namu damage in thirty Solomon Islands watersheds has been undertaken by Stephens *et al.* (1986). The survey involved the stereoscopic interpretation of specially flown 1:25,000 colour photographs to provide information on the type and extent of damage to forest vegetation, and landslide and flood damage. The imagery assisted the Solomon Islands authorities with safety and salvage operations.

   Carr and Stephens (1986) describe the use of colour video for mapping erosion caused by two intense rainstorms in New Zealand. In both surveys, airborne video proved effective in providing base information for storm damage assessment. Video proved to be a near real-time tool, providing storm damage information over large areas in a hitherto impractical time frame.

2. *Flood and landscape hazard mapping.* Colour aerial photographs of the Solomon Islands acquired for cyclone damage mapping (Stephens *et al.* 1986), have also been used to map flood and landslide hazards (Trustrum *et al.* 1990) for the major watersheds of Guadalcanal Island. Mapping was undertaken by a combination of field observation (primarily geomorphology of the flood plains, and characteristics of sloping land) and interpretation of the 1962 aerial photographs and the post-Cyclone Namu aerial photographs.

3. *Erosion control and crop suitability planning.* Aerial photography has underpin land use capability mapping, erosion control planning and crop suitability derivations for Atiu Island (Cook Islands) (Jessen *et al.* 1990, Miller 1990, Trangmar and Jessen 1990). Colour aerial photographs flown in 1988/89 by the Cook Islands Department of Lands, were used to assist mapping soils, vegetation, erosion and land use. The photographs were also used to produce a digital orthophotograph basemap (Dymond 1992). The digital basemap facilitated recording land unit boundaries before input into a GIS. The digital basemap can also be used as a backdrop for GIS operations, and as a vegetation, land use, and erosion status map.

4. *Vegetation cover change detection.* Remotely-sensed images of an area, on different dates (time-sequential), can be used to detect changes in the physical environment. Stephens and Cocks (1991) describe how SPOT PA imagery in combination with digitised time-sequential aerial photographic data has been used to determine the amount and areal extent of vegetation and bare ground changes that have occurred over a 23 year period.

16.0 Concluding remarks

There are four important qualities of remotely-sensed images relevant to natural resource management:

- They contain objective data;

- The data can be quantified;
- They are in a permanent form;
- The data can be manipulated by computers and integrated with other spatial (GIS) datasets.

The use of remotely-sensed data by appropriately trained and equipped staff should be able to provide the following for agencies involved in natural resource management:

- An inventory of natural resources;
- The ability to monitor the areal extent and spatial location of changes of relevant natural resources;
- Assistance in the selection of sites for specific studies;
- Assistance in determining the relationship between land management and land degradation and/or sustainable land use practices.

Application projects have demonstrated the considerable potential of remotely-sensed data for land resource management. World-wide, and more particularly in the South Pacific, there are few operational uses of remotely-sensed data for natural resource management and environmental monitoring.

The key to making remote sensing operational for natural resource management will not be the use of a single sensor to solve all issues, but the integration of data from a range of sensors with other geographic and socio-economic information. This will only occur when there is a mature service sector within the South Pacific which provides help, guidance, and data to potential users who have a problem requiring the use of remotely-sensed data and spatial information systems. The suppliers of remotely-sensed dat should relieve users of heavy pre-processing workloads, and make the data more suitable for use by the Pacific user community. Data should be made generally available as products that are easily integrated with other data sets and GIS.

The South Pacific user-community is generally unaware of the potential of remote sensing and spatial information systems. When resource managers within the South Pacific become familiar with remote sensing and spatial information systems, the gap between the potential use of remote sensing and its actual use will be reduced. With accompanying growth in use of remotely-sensed data for resource management, users' confidence in its value will be enhanced. Only then will the benefits of remote sensing be realised for resource management and environmental monitoring activities in the South Pacific region.

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PART THREE

REPORTS FROM COUNTRIES AND ORGANIZATIONS

COOK ISLANDS GIS PROJECT

by

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The principal government agencies directly involved in the project are the Department of Survey (DOS), Ministry of Agriculture and Forestry (MOAF), the Ministry of Works (MOW) and the Conservation Services (CS). DOS is the executing agency for the project and the Chief Surveyor (myself) is not only the contact point between the New Zealand Consultants and Government but is also chairman of the Steering Committee.

The steering Committee is in the process of finalising details on the draft **PROTOCOL FOR SHARING DATA AND RESOURCES** agreement.

Training of GIS operators in New Zealand (one from each of the above agencies) were completed by the end of 1993. DOS is responsible for CAD training.

About 80 per cent of all cadastral data have been captured using Auto/CAD; soils, streams, roading and contours have all been captured by scanning of existing maps — these all married in quite well with the accurate cadastral base maps.

Remote sensing

DOS also provides an aerial photography service — small format camera mounted on a local aircraft. The client pays for materials including developing printing and the hire of the aircraft. DOS otherwise provides the necessary technical service free of charge but retains all negatives.

GIS/LIS AND REMOTE SENSING APPLICATIONS IN FIJI

by

Kemueli Masikerei,
Department of Lands and Survey, Fiji

1.0 General

The introduction of computerised information systems, whether it be geographic information system (GIS), land information system (LIS) or remote sensing (RS) is at its infancy in Fiji. It is encouraging to note the increase in awareness with decision makers, developers, academic institutions and the public at large of the benefits and usefulness of these internationally accepted technologies. The result is the rapidly expanding activities in GIS/LIS/RS within government and non-government agencies. This is putting presure on the Fiji Land Information Systems (FLIS) and the operational systems in other organisations to make available additional products and services to provide for agencies activities.

2.0 Advisory mission to Fiji

A request by the Fiji Government through the Ministry of Foreign Affairs was forwarded to ESCAP regional advisor on remote sensing and GIS to render advisory services to related governmental agencies on matters with regard to the application of remote sensing and GIS technologies in the natural resources and environmental management. Consequently an ESCAP offical was in Fiji and attached to the Fiji Land Information System Support Centre (FLISSC) in Suva from 13-26 March 1994.

The official visited 19 government agencies from 9 ministries including the Ministry of Lands, Mineral Resources and Energy; Ministry of Agriculture, Fisheries and Forest; Ministry of Public Works and Utilities, and also visited several regional institutions namely SOPAC, USP and UNEP/GRID offices.

The official's report was presented to the Fiji Land Information Council (FLIC), the body responsible for land related information systems in Fiji and distributed to the various agencies visited and other relevant organizations for comments.

Responses received were very encouraging. The evaluation and report of the GIS/LIS/Remote Sensing environment in Fiji came at an appropriate time and there was full agreement and support with the insights and conclusions. There can be little doubt that remote sensing and GIS/LIS play major roles in the future land and environment management processes in Fiji. The survey of the various agencies showed that there were many programmes either under way or planned where natural resources and environmental data would be a major requirement.

There was a message in the report relating to the current availability of remote sensing data and it is expected that the reality would be that it will be some time before a continuous source of data will be accessible in Fiji and the other Pacific islands. There was also a strong message about coordination and support, and a total cooperative approach is very much necessary. Therefore, we see the national and regional growth in the GIS/LIS and remote sensing technologies as an integrated, cooperative process which has progressed very well so far in Fiji, with continued support and involvement of the FLIC and the many agencies concerned.

Some of the report's highlights are included in this paper.

3.0 GIS/LIS and remote sensing application in Fiji

For quite some years, in fact since 1951 (1951-1953 full photographic coverage of Viti Levu and Vanua Levu), Fiji has been satisfied with the use of aerial photographs as source data for mapping and other use applications. In the middle of last year (1994), the Australian Aerial Mapping (AAM) Surveys was engaged in aerial photography to cover the whole of the Fiji islands (land and reef areas) as part of FLIS Stage II Project.

Remote sensing is something recently introduced. Parallel to this, GIS/LIS technology has been established within a number of organisations in a coordinated and systematic manner with FLIS playing the leading role.

A brief outline on the applications of GIS/LIS and remote sensing in Fiji follows:

3.1 Department of lands and surveys

The operational Fiji Land Information System was established in early 1992 when Cabinet was convinced to computerise the core land related data that exist within the Department of Lands and Surveys, Register of Titles and the Native Land and Fisheries Commission (NLFC).

The two-year (1992/1993) FLIS Stage I Strategy Paper identified twelve projects and covered fiscal/legal subcategories (survey/titles/valuation/cadastral) of a LIS. The majority of the projects have been completed and available in digital or hardcopy formats. This has been possible with the assistance of the New Zealand Government in the form of funding and manpower expertise.

The notable results of FLIS Stage I is the computerisation of five government offices, namely; the Department of Lands and Surveys Headquarters (Survey Plan Index/Journal, Lease Administration, Computerised Cadastral Mapping System, Road Index, State Land Register, Geodetic Database), the Registrar of Titles (Titles Index/Journal), the Valuation Office (Valuation Assessment Records), the Native Land and Fisheries Commission (Native Land Commission Reports, Vola ni Kawa Bula (VKB)), and the Director of Town and Country Planning Office (Planning Applications) and the FLIS Support Centre, the focal point of the FLIS.

The five Local Area Networks (LAN) are all linked by radiowave technology thus establishing one Wide Area Network (WAN). A user only has to visit one of the LAN's in order to access data from any other participating agencies therefore creating a 'one-stop-shop' concept. Remote access is available through the telephone with a modem.

The second stage (1994/1995) also with the support of the New Zealand Government is well on the way and looks at socio-economic (Bureau of Statistics Mapping), utilities/infrastructure (Water/Sewerage Mapping) and natural/environmental data. Thirteen projects have been identified and the priority area lies in the establishment of a national Digital Topographical Database (DTDB), a product of the aerial photography exercise recently completed. In addition, the DTDB would assist in the acceleration of the production of Fiji's 1:50,000 topographical map series and as bases for thematic mapping such as census maps, street maps etc. Topographical information in database format is sought by a number of resource agencies involved with forestry, mineral resource development and agricultural planning as well by major development investors interested in specific projects. The general public and agencies like the Fiji Military Forces seek completion of the standard topographical maps.

Presently, the Photogrammetric Unit of the Department of Lands and Surveys is undergoing an upgrading process of photogrammetric machines from analytical to digital capture capabilities with necessary training carried out and planned for the operators.

We foresee that the FLIS programme will shift from an emphasis on data capture/systems building to extended applications development over the next couple of years. To fully integrate and analyse the relationships between a topographical database, the parcel based cadastral database and associated systems (e.g. forest cover) would require a raster based system. The full environmental benefits in resource management terms will only become available when the parcel or vector based components of the LIS are merged into the raster based physical data collected by resource management agencies. This would be an area of investigation by the FLIS Advisor.

3.2 Native Land Trust Board (NLTB)

The Native Land Trust Board introduced its Land Information System in January, 1988. It was given the task to capture digitally all land related data on customary ownerships on Native Land, the various developments and the resources pertaining therein.

With limited manpower, the NLTB LIS Project team had managed to complete this major exercise in April 1994 and further went on to phasetise the database to facilitate data extractions on any required scale and locality. This was completed in December 1994.

The NLTB information system will shortly embark into a major restructure and redevelopment programme. One of the main areas of focus is the availability and accessibility of data derived from remote sensing/GIS technologies to assist the management in the decision making process and to provide better control of the administration, development and use of the natural resources on Fijian owned land for the benefit of the NLTB Stakeholders, the tenants and business partners.

3.3 Department of environment

The Department of Environment is a new specialised entity within the Ministry of Housing, Urban Development and Environment and is responsible for enormous tasks. Cooperation and support from concerned agencies is necessary in order to maintain and develop a total approach to its heavy duties.

The development of remote sensing applications and a GIS/Environmental Information System has been identified as a priority project for the Department. An environmental database would be developed, linking it to other operational systems with Forestry, FLIS, SOPAC, Mineral Resources, Bureau of Statistics, etc. and the regional Pacific Island countries.

A technical Officer (Systems) has been appointed as Project Officer.

3.4 Department of forestry

Forest Monitoring and Forest Land Management are major applications of Remote Sensing and GIS activities in the Forestry Department. Hazard mapping, water catchment monitoring and disaster assessment need this forest monitoring and mapping as major input.

At 1:50,000 scale a Forest Monitoring System has been established containing three main components:

1. Digital image analysis system (ERDAS VGA, ERDAS PC, ERDAS Imagine). A digital layer of the up-to-date forest cover divided into dense, medium and scattered forest, hardwood and pine plantation and mangrove is available for the area of Fiji. A full coverage with Landsat TM data from 1991/1992 is available on optical disks. Additional SPOT scenes recorded in 1994 are available on CD-ROM;
2. Relational data bank holding information from over 500 sample plots distributed randomly over Fiji's natural forests. Detailed information is stored about woody biomass, species, regeneration potential, minor forest products such as medicine plants etc.;

3. Forestry GIS (ERDAS, ARC-INFO). The system was developed in Germany and holds spatial information such as a digital terrain model (DTM), the soil map of Fiji, slope map, seasonal and mean annual rainfall, declared reserved areas, e.g. water catchments, areas of high biodiversity. GIS is being used to analyse and map forest function areas. A further data bank is available for hardwood plantations.

At 1:10,000 scale an analytical photogrammetric instrument is available (Visopret, ZEISS) to map contour information, river etc. to provide maps for the planning of logging areas. The map production and map editing is carried out by a different GIS software (MicroStation, INTERGRAPH). For detailed mapping of logging areas a GPS main station and 'hand-held' receiver are available (Trimble Navigation). These projects have been established by Australian aid. In addition, a European Commission funded Plantation Survey Project (spatial database) had been established to map the outline of plantation areas using GPS technology.

Further, the Japanese Government had provided 'hand-held' GPS receivers and digitising facilities for mapping and updating logged-over areas in natural forest cover.

All project areas are linked by network and users can access data remotely with a modem and hopefully by 'e-mail' in the near future. A wide range of output and input formats as well as devices such as streamer, optical disk drive, tape drive are available for use.

3.5 Mineral Resources Department (MRD)

Satellite remote sensing was introduced first in 1988 with a pilot study on the coastal area of Ba Delta in cooperation with SOPAC. Processing was done party in SOPAC using Microbrian and partly in Station Polynesienne de Teledection (SPT) in Tahiti.

Satellite imagery and Digital Terrain Model (DTM) was used in South East Viti Levu Hazard Landslide Mapping Project conducted cooperatively with the British Geological Survey (BGS). This project is designed to end in mid 1995 with the implementation of the system in MRD with necessary training.

MRD is also in the process of storing and distributing in digital form geophysical data concerning mining exploration and other types of data such as SLAR (Side Looking Aperture Radar) data. To process this exploration data, MRD is now equipped with a Mine Resources Assessment Package (GDM) which will be closely linked with MRD GIS.

Projects (e.g. Suva Peninsular Coastal Mapping Project) targeted on specific areas at larger scales (1:50,000 and larger) have already been set up in addition to the continuation of the more general databases development despite a limitation in human resources.

MRD supports MapGrafix GIS software in connection with the FoxPro database to digitise and capture data on earthquake epicenters, oil exploration seismic surveys, marine geophysical and bathymetric data in Fiji EEZ, geological drillhole and geochemical analysis data (water and sample rocks).

Once the Digital Topographical Database (DTDB) is developed by FLIS, MRD would be looking at the possibility of using the DTDB and the subsequent digital topographical maps as a base for the production of digital geological mapping series.

3.6 Department of meteorology

The Meteorological Department is charged with providing meteorological services to the nation and with continuing its function as a regional weather forecast centre for the surrounding nations in the Pacific.

Though the Department has the capability to receive high resolution (Stretched-VISSR) data from both GMS and GOES, the software remains untested as the satellite has been out of operation.

A F$3 million weather radar has been installed at Nadi to monitor more precisely and to allow more timely warnings of severe weather systems including tropical cyclones. An application to expand its existing set up costing about F$20 million funded by a grant from the Japanese Government, is still under consideration. Though there have been some positive developments lately in this regard, it is not certain as yet that the project will be approved. The proposal includes satellite systems upgrading, in particular the installation of new systems for NOAA HRPT data (1 km resolution imagery from polar orbiting satellite) and GMS S-VISSR (1.25 km resolution Visual and 5 km Infra-red). A similar proposal rests with the United States of America.

Whatever the source, the Department of Meteorology is very hopeful of receiving a system for NOAA AVHRR data within the next few years.

3.7 Department of agriculture (Land Use Section)

Since the establishment of the Land Use Section, a lot of work in relation to soil survey, land appraisal and crop evaluation have been carried out in Fiji with assistance from a number of overseas donours. Just recently, the Soil and Crop Evaluation Project (SCEP) was established funded jointly by the New Zealand and Australian Governments. The intention is to produce semi-detailed soil maps of Fiji of 1:50,000 scale. 20 sheets covering Viti Levu will soon be published out of the 38 map sheets to cover the whole of Fiji.

These projects in total have produced a great amount of land related data and it is anticipated that most, if not all, would be computerised for GIS analysis.

3.8 SOPAC

With its Technical Secretariat in Suva, SOPAC has become a subregional centre for data, knowledge, facilities and services in the field of remote sensing and GIS. Presently it supports ERDAS remote sensing image processing system and ARC/Info GIS software. It has also a French developed OSIRIS spatial image processing software package installed in SUN station. A MapInfo vector based GIS system is also in place.

SOPAC recently received several SPOT Images as part of the MOU being signed with other regional organizations including FFA, SPC, SPREP, USP as well as the remote sensing centres SPT and LATICAL. These images are an example of how this cooperation works. They have been purchased by SPT in Tahiti, but as SOPAC has a requirement to undertake analysis of these areas, SOPAC paid the 15 per cent royalties on the copyright as opposed to the full purchase price. Areas covered include Tuvalu, Kiribati (Abiang), Tonga, and Cook Islands (Penrhyn). In addition, SOPAC had carried out some work in cooperation with the Mineral Resources Department on the use of DEM to identify faults in Kadavu Island.

3.9 University of the South Pacific (USP)

USP is a regional (12 nations) institution dedicated to human resources development.

USP established the GIS Unit in 1993 to provide training and education in the new spatial technologies. Under the direction of Dr Bruce Davis the Unit is actively involved in supporting campus and community GIS progress. A second year course, 'Introduction to GIS' is offered in the Geography Department and it is encouraging to note the large number of students enrolled over the past two years from both the campus and from the staff of government and non-government agencies. Other courses are planned for the near future. Also, a training programme leading to a Diploma in GIS in under development

which will offer professional certification and additional academic specialization. Advances in telecommunications and computer technology are being used to create new training course delivery mechanisms, such as distant learning and self-paced modular teaching.

There is a need to extend the information systems training component to ensure that enough staff are trained to cater to Fiji's needs in database design and programming, systems management, and network maintenance as associated with the operation of FLIS and similar systems in other organisations. It is acknowledged that there is a shortage of database programming and network management skills in some agencies. There is also a need to place greater emphasis in training in end-user applications. Accelerated local and regional institution building would be an appropriate means to help strengthen local support for these activities.

4.0 Putting in place appropriate structures

The large number of government departments and statutory organisations that are involved in land information processes necessitate some structure to ensure a coordinated approach to the development of a national information system, thus the establishment of the Fiji Land Information Council (FLIC). The members consist of senior representatives of the agencies directly involved in the implementation of the national LIS and presently involve ten Permanent Secretaries including the General Manager of the Native Land Trust Board.

The FLIC is responsible to the Minister for Lands, Mineral Resources and Energy and meets once a month.

Apart from others, the main functions of the FLIC are:

— The development and coordination of all LIS projects;
— Funding;
— Formulation of policies (data standards, custodianship, pricing, privacy etc.);
— Training and education;
— Management and direction of the FLIS Support Centre.

A second structure was also necessary. Whereas the FLIC is responsible of interdepartmental coordination and policy, the FLIS Support Centre was established to manage the council's decisions. It is the 'action group'.

Two other groups have been formed namely the GIS/RS User Forum and the Utilities Group, and comprise technicians and experts directly involved in the technology. Group discussions focus on issues such as data transfer, data sharing, problem solving, and projects updates.

5.0 Immediate needs

Of major concern to the Fiji Government and other Pacific island countries is the wise use of our often non-renewable, water and land resources and the environment as a whole. The sustainable use and care of these domains is basic to prosperity and long-term survival.

There is no doubt that the use of aerial photograph, satellite imagery and geographic information system (GIS), in conjunction with sound resources management will provide a key input to the development and management of the natural resources of the Pacific island nations. This is very important considering the growing pressures on population growth, deforestation, the green house effect, water and air pollution, environmental maintenance etc. Fiji's immediate needs include.

5.1 *Access to data*

For Fiji, the main issue is the lack of access to satellite data and resource management information techniques and technology for the survey, evaluation and monitoring of resources and the environment for development and conservation. Fiji's isolation in these areas the been voiced in various forums. The main reasons/limitations, apart from others include:

5.1.1 Technical

The Pacific island countries are small in land area and population compared with other nations, particularly in Asia, but we represent some 10 per cent of the members of the United Nations and cover about 20 per cent (EEZ) of the earth's surface. Although we are most vulnerable to global changes and climate conditions (cyclones, earthquakes, tsunamis, volcanoes etc.), we do not have a satellite ground receiving station.

There are a number of satellites (Landsat/SPOT/NOAA/JERS) which could collect data over the Pacific region but do not. One of the reasons is that the data is not downloaded. Moreover, the Pacific islands, particularly Fiji, are well known for their continuous cloud cover which reduces the opportunity and quality of the imagery but the technology is available to counter this obstacle.

The concept of establishing a **mobile ground receiving station** to download Landsat, ERS-1 satellite data in the Pacific region is a solution which Fiji fully supports. The Pacific region would be in a position to guarantee a continuous supply of satellite data.

5.1.2 Financial

In this context, remote sensing data availability at a marginal cost for research and development (R and D) and national disaster purposes could be considered.

Fiji does not have the funds to set up a mobile ground receiving station. National project either planned or in progress rely heavily on overseas aid. There are a few agencies (SOPAC, Forestry Dept. Mineral Resources Dept.) which have the capability of processing satellite data.

5.1.3 Communication links

There is definitely a lack of communication links between Fiji and the countries of the Pacific region and with the outside world in two important areas:

(a) For data: collected and stored in developed countries. It is very difficult or almost impossible to access them;

(b) For knowledge: there is a need to upgrade the technology.

Improvement in communications can be addressed by space technology through Networking (Regional User Network), Internet Global Network or PEACESAT.

5.2 *Training*

The training component in these technologies cannot be overlooked. Unfortunately, it is felt that training in GIS/LIS and remote sensing so far has concentrated on how to operate the systems. It is important to look beyond the operators to cover the users, users of result, the decision makers and systems managers/analysts and more advanced software developers who can modify or develop in-house software tailored to suit our needs.

On the regional level, the reality is isolation, low technical resources, lack of computer literates, lack of training funding etc. which when considered in total reveals a definite need for an appropriate regional

training programme to be put in place now at this early stage of GIS/LIS/RS implementation. It is encouraging to note that USP is looking into this. What USP needs is the support and commitment from supporting member countries and donour agencies.

In-country and regional seminars and workshops should be promoted and continue to enhance awareness.

5.3 Data sharing

It is encouraging to note the various successful projects funded and carried out by donour countries such as Japan and regional agencies such as ESCAP in Asian countries which have been adopted and implemented at the national level. These projects cover subjects such as deforestation and reforestation, remote sensing and GIS studies, changes in tropical forest, re-green movement (local forest/mangrove). Procedures on planning and implementation both at project and national levels are well documented. It is recommended that these documents be made available to other Pacific island countries where similar activities can be conducted. Definitely, these documents could be used as guidelines by decision makers and planners in executing their tasks on sustainable environment/natural resources and management.

6.0 Fiji Government support

The Fiji Government has actively promoted and will continue to promote the ordered and coordinated development of GIS/LIS/RS technologies through the Fiji Land Information Council.

The Fiji Government also wishes to express its continuous support to UNDP and ESCAP and other regional organizations on initiatives whether in training, project or scientific studies oriented under their programmes in Fiji and the Pacific region but would like that much more attention and commitment be directed to the small Pacific island countries by regional governments and bilateral and multilateral donour agencies on the issues raised above.

7.0 Conclusion

It is said that 'money in the hands of a few is no more the source of power but INFORMATION in the hands of many'. The systematic method to collect, store, update, analyse and distribute/share information is another story. Here, technology is not the issue but how well we design/construct, manage and utilise these data to meet total needs in its application and experience the usefulness and full capabilities of these internationally accepted technologies.

DATA INTEGRATION ISSUES

by

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A lot of manipulation of data using GIS involves "putting them together", whether by importing data, by disseminating, exchanging, mixing or merging them. Data integration is indisputably one of the key issues in successfully implementing GIS/RS technologies.

This presentation will highlight four major points concerning data integration:

(a) File format translation;
(b) Projection/spheroid conversion;
(c) Scale;
(d) Data quality and standards.

1.0 File format translation

Most modern GIS software provides GIS file format translation capabilities, at least for the most common format such as the DXF format. However, all those GIS have diverse ways of understanding and coding their information. Therefore, even with the available translation software, it is still likely that some information could be lost during a translation, especially if the information is rather complex.

File format translation issue is one of the first problems that will arise in data integration. If not carefully tested and assessed, it is likely that it could use a substantial amount of unplanned resources (time/money). However, there is a great deal of chance that some other users came across the same problem, already solved it and are ready to help, via, for example, users groups.

2.0 Projection/Spheroid conversion

In order to be combined together into a map which is a two dimensional document, data should be projected into a unique system. As for file format translation, modern software offers conversion between various projection and spheroid.

The limitations that could be encountered often originate from a lack of information concerning the data to be converted. Incomplete information concerning the projection and spheroid used for representing data could actually forbid the accurate use of conversion software.

If information about projection and/or spheroid is missing, one way out, is to perform a geometrical transformation, as long as a proper registration point could be identified.

There again, as for the file format conversion, the problems that you will come across have most probably been solved already by another user.

Use of technologies such as GPS is very useful in order to acquire new data with accurate registration.

3.0 Scale

GIS has often been qualified as scale free. However, the data which are represented using GIS are not scale free. The information is accurate, and could be used effectively within a certain range of scale even if GIS software offer the capability to display it at any scale.

It is essential to associate to GIS information the scale at which it could be used.

4.0 Data quality and standard

Lastly once issues concerning file format, projection and spheroid, scale have been dealt with, two sets of data can be integrated into one GIS document. A user will eventually make a decision or judgement based on the map that was produced by combining several sets of data. Therefore data should not only be accurate in terms of geographical position, but also in terms of the information that it carries.

It is essential that a sufficient data quality is ensured. That could be achieved by setting data standards against which data could be validated.

5.0 Conclusion and considerations in implementing GIS

Issues related to data format are usually the more obvious and first met. They are linked with software and hardware issues which relate to short-term commitment. However, issues related to the data itself are less obvious but represent a longer-term commitment and are much more critical to the success of the project.

Data standards are essential to minimize problems of exchange, to ensure that data are more usable, valuable.

Data standards should be decided on the needs of not only the current users, but also the future users or clients.

Coordination and cooperation are one of the keys to success in implementing GIS, especially in regards to the minimization of the potential problems related to data integration.

THE NATIVE LAND TRUST BOARD EXPERIENCE

by

Tevita Wara, Native Land Trust Board

1.0 The Native Land Trust Board's contribution to this Workshop is to try and relate briefly our experiences as user/end user of the GIS technology for the last seven years and perhaps share with other participants their own experiences in their own country.

2.0 Historical background

2.1 Native Land Trust Board (NLTB)

The NLTB is a statutory body whose main responsilbility is to administer and control the use of Native Land and its resources for and on behalf of its customary landowners in accordance with the Native Land Trust Act Cap 134 of the laws of Fiji. In brief the Native Trust Board acts as Trustees for and on behalf of the various customary landowners or indigenous landowners in the Republic of Fiji. The indigenous landowners owned 83 per cent of the land in Fiji.

2.2 Native Land Trust Board Information Systems

In 1975 the NLTB initiated its computerised information system. **In 1986, it decided to carry out a major development.** A major review was carried out in 1986 to expand and centralise NLTB information systems with the use of Vax Digital Mainframe. To date, with continual development of its information systems, the NLTB has managed to fully automate all its administrative functions.

3.0 NLTB-LIS

As a part of the major review to expand its computerised information systems in 1986 the NLTB decided to develop its Land and Information System to enable us to enhance the various services we rendered to our main stakeholders, the indigenous landowners, our tenants and various business partners.

3.1 Software/Hardware

The NLTB decided to purchase Informap III software/hardware to run its Land Information System in 1987. Informap III is supplied by Synercoun of Houston, Texas, United States. Other supportive softwares are:

(a) INFORQUEST — Reportwriter;
(b) EMIS — (Environmental Management Information System) for GIS applications;
(c) INFOPLOT;
(d) COGO;
(e) PLUS/PLUS SUB ROUTINES.

3.2 NLTB-LIS database

The NLTB-LIS database was developed by a database consultant in August 1987 with the assistance of local staff culminating with the successful implementation of a pilot project. Since it was the first introduction of LIS technology in Fiji, it was decided to extend the scope of the database to include all areas of interests to the Ministry of Fijian Affairs and related organizations, especially on natural resources, infrastructure, communications and statistics. It must be noted that in the use of different data types from sources outside the Ministry of Fijian Affairs, related organizations and statutory bodies, the

consent of the data owners was first obtained and they were very much aware of all activities during the capture of the data concerned. Owners of these data are clearly identified in the NLTB-LIS Scheme. Updating of these data will be controlled by data source owners.

3.3 Work progress

Except for cadastral maps on the basic scale of 1:12,672 in the Northern Division, our data capture programmes for the capture of customary ownership of native land in Fiji was completed in April 1994. Large scale mapping of urban and peri-urban areas of Fiji was captured by FLIS Support Centre.

3.4 Facetisation

For the remainder of 1994, we managed to facetise the NLTB-LIS database on the Base Unit Scale — 1:25,000. This provides a continuous and seamless map of Fiji which also facilitates the extraction of any data set anywhere in Fiji at any scale.

4.0 Review of the NLTB information systems

The NLTB will in the very near future carry out a major redevelopment of its information systems. This development will involve a major restructure exercise and a move to the use of micro-computers and the gradual phasing out of the Digital Vax Mainframe. This review was prompted by requirements by users who have demanded more services from the current information systems.

4.1 Future development of NLTB-LIS

The following are the proposed development of the NLTB-LIS:

(a) Redevelopment of the NLTB-LIS scheme in accordance with the user requirements;
(b) Restructure of the NLTB-LIS database;
(c) Purchase of a new GIS software/hardware;
(d) Introdution PC Micro-computers;
(e) Development of LAN and WAN to cater for the 3 divisional offices including the Head Office.

4.2 Identification of user requirements

We are still continuing with research and identification exercises.

5.0 Current work programme

We are using and manipulating data extracted from the NLTB-LIS database to carry a major and thorough land-use exercise involving agricultural leases on native land in the cane belt of Fiji. It is anticipated that this major exercise will continue for the next eighteen months.

6.0 Our support of FLIS/Others

(a) We will endeavour to continue our support to FLIS and FLIS Support Centre as a core or hub of the Land Information Technology in Fiji;

(b) To maintain our communicational link and continue with the Data Transfer Exercise with the use of SIF translators to our mutual benefits;

(c) To assist each other with the completion of the JOINT ACTION PLAN.

7.0 Our support to the Fiji land information council

We will foster our continuing support to the Fiji Land Information Council and the important role it will play in the development of Remote Sensing/GIS technology in Fiji.

8.0 NLTB-user/End user

The NLTB can be counted on as one of the major user/end user of the LIS/GIS technology bacause of its unique position as trustees to majority owners of the resources both on land and in the sea. NLTB will rely on other users of the LIS/GIS technology to provide suitable/accurate data to enable us to fulfill our obligations and to provide better management of our natural/marine resources on behalf of the owners.

9.0 The NLTB — experience

9.1 To maintain data integrity

Ensure that both attribute/graphic data are from original source documents. Do not expect any less.

9.2 Data accuracy

Use the best and most accurate map controls available

9.3 Data verification

Carry out a thorough data verification process before storing data as permanent record.

9.4 Storage facility

Ensure that storage facility and space is available all the time.

10.0 NLTB — support to the development of remote sensing/GIS technologies

The Native Land Trust Board will support fully the continuous development of Remote Sensing/GIS technologies and contributions from ESCAP. We hope that the future benefits of data derived from Remote Sensing/GIS technologies will be utilised by all regional governments in the Pacific for the maximum development and control of their scarce natural resources.

In conclusion I would like to add that the Native Land Trust Board fully supports the recommendations in the Beijing Report and the ESCAP report on the mission to the Government of Fiji.

REMOTE SENSING AND GIS APPLICATION FOR MONITORING FIJI'S NATURAL FOREST

by

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Forestry Department, Fiji

ABSTRACT

A national forest inventory was carried out for Fiji's natural forest and forest plantations. The detailed database for all hardwood plantations and natural forest are now available locally. Fiji's natural forest inventory also included the production of forest type and forest function maps. The mapping required satellite data analysis for forest type stratification and GIS technology for the definition of forest functions. There were some unexpected challenges and problems which undoubtedly other South Pacific countries will face. These were the acquisition of cloud free satellite data and the inclusion of local knowledge. A practical solution is the installation of remote data and the inclusion of local knowledge. A practical solution is the installation of remote sensing and GIS technique in Fiji, operated by local foresters on a permanent basis and supported by regional organizations in the region.

1.0 Introduction

The lack of up-to-date information about Fiji's natural forest resources development was expressed by Fiji in Geneva and a natural forest inventory was decided along with the Tropical Forestry Action Plan. The German Agency for Technical Cooperation (GTZ) then contracted the consultant companies GOPA/SIGNUM to complete this task in 24 months.

The expected output was:

- Statistical report on current status of natural rain forest;
- 1:50,000 scale map showing forest types and forest functions.

The forest inventory covered all the main islands forest areas and forest tree species independent of their social and economic values. It took also into account regeneration potential, minor forest products and environmental parameters. The field survey was completed in 1992 whereas the map production is not fully completed yet.

2.0 Components of Fiji's natural forest inventory

2.1 The terrestrial survey

Over 500 sample plots have been measured during the field work. These plots have been randomly distributed throughout the country. The three four-men teams for the inventory consist of a forester, a treespotter and two labourers carrying out measurement of all trees, natural regeneration counting and the identification of plants used by the villages as food or local medicine. The Department of Environment enumerated birds in the vicinity of plots. All data are stored in a relational database (dBASE) for linkage with spatial information.

2.2 Digital satellite image analysis

Recent aerial photographs were not available, incomplete and too expensive to produce. Landsat TM data was chosen because of its higher radiometric content and low cost compared to SPOT. Many cloud covered areas were replaced by cloud free parts of a corresponding scene. The separation of forest cover area from non-forest area processed in Germany included the forest stratification into scattered, medium and dense forest.

2.3 The geographic information system

A PC raster databased GIS (ERDAS) was an acceptable software for the task. The information layers are available in the form of digital maps at the Forestry Department. It can be shared by other government departments. This information includes:

- Soil map of Fiji;
- Ditital terrain model and slope map;
- Declared areas (declared reserves, water catchments etc.);
- Areas with high biodiversity;
- Mean annual rainfall;
- Seasonal rainfall;
- District and province boundaries;
- Road network;
- Major rivers;
- Hardwood, coconut and pine plantations;
- Forest cover of last inventory (1969);
- Forest types (forest cover 1991/1992).

The **"forest function map"** has been the resulting combination of these overlays. The forest function map shows the forest cover (dense forest, medium forest and scattered forest) and management categories indicating Reserved Forest, Protection Forests and Multiple Use Forest.

The "forest cover (1969)" was compared with the "forest types (1991/1992)" to establish a "forest change" layer.

3.0 Installation of forest monitoring system

The inventory design was upgraded to be able to monitor the forest change permanently and for any change detection in tropical Fiji. Therefore, a modification was forced on all three components including the terrestrial survey, the satellite data analysis and the GIS analysis.

3.1 Satllite image analysis

A PC base digital image analysis system was installed by the project in the Management Services Division (MSD) of the Forestry Department. This system includes input facilities to import all types of satellite data. User friendly image analysis software along with training allows the forestry staff to stratify the forest cover using their field experience. Apparently, further stratification is possible with additional test areas.[1, 2]

3.2 GIS analysis and data capture

Upgrading of software and hardware made map production possible within the MSD and enabled the direct data exchange by network to other projects in the Division. Parts of the hardware now improve

[1] see Tuinivanua O., Possibilities of Mangrove Mapping with Landsat TM Data, GIS and Remote Sensing Newsletter, October 1993.

[2] see Tuinivanua O., Raintree as a New Forest Type, GIS and Remote Sensing Newsletter, December 1994.

the map production. The problems of recalculation from one coordinate system to another is solved by an expert of an AIDAB funded project within MSD. His locally designed software package was available to other departments.

3.3 Terrestrial survey

One team continues to establish permanent sample plots nation-wide. The plots concentrated on secondary forests including forests not initially enumerated. The MSD also established an additional database containing socio-economic data. The field team collecting data to investigate the socio-economic benefits of Fiji's forest.

4.0 Problems with Fiji's environment

The inventory was planned in Germany by experts who have experienced the tropical countries. However, the South Pacific countries have its own unique features and characteristics making it different from other countries with tropical rain forest.

4.1 Satellite data acquisition and analysis

The project **data acquisition** was based on two Landsat satellites that were fully functional in orbit, Landsat 4 and Landsat 5. However, only Landsat 4 was able to download data recorded from Fiji via relay satellite to the ground antenna in the United States SIGNUM in Germany had to purchase 19 scenes (instead of 6) to mosaic a cloud free coverage of Fiji. Unexpected haze over forest cover which was not visible in the quick look images created other difficulties for the digital image classification. The forest stratification using satellite data was delayed due to the mentioned reasons.

The satellite data received from Germany had been **geometrically corrected** to UTM. However, the image data had to be corrected to Fiji Map Grid. Further, all pre image enhancement modules such as destriping do not work with geocoded data.

In other tropical areas such as West Africa or South America, there is often a structural difference in canopy between virgin or dense forest and logged forest, because the logged forest has a rough and shadowy canopy. The canopy closure is often a good indicator for the forest density. This is highly irrelevant in Fiji. The **canopy closure is not related to forest density** in terms of standing biomass per hectare. Due to frequent cyclones the forest has a rough canopy structure. Furthermore, tree ferns as a pioneer species covers the land slides, have no woody biomass but exhibit tree reflections in the satellite image.

The geographical distance between the digital image processor and the foresters with local knowledge has been an ongoing problem. It's also an **economic challenge** in developed countries to do all computer work by foresters with experience in tropical rain-forest. Such an operator will not realise many phenomena and he will not ask the foresters in the South Pacific Country, even if a good communication link such as fax and e-mail is established. For example the seasonal effect (defoliation) with African Tulip *(Sparodae campanulata)*, Raintree *(Samanea saman)* or Mahogany *(Swietenia macrophylla)* will not be recognised by an off shore operator.

4.2 Terrestrial survey

The review of the forest legislation carried out by an FAO expert did not include the forest definition. The boundary between **forest and non-forest was not defined.** The plots were checked in Germany with satellite images if they were located within or outside the forest cover. A non local operator will always underestimate the forest area. However, there were secondary forests mapped as non-forests in the last inventory.[3]

[3] see Tuinivanua O., Change Detection of Fiji National Forest Cover Using Landsat TM Data and GIS Techniques, GIS and Remote Sensing Newsletter, September 1994.

4.3 Spatial data collection and analysis

Much spatial information already available in the country had to be redigitised because it was impossible to obtain these map layers due to administrative and technical reasons. Many donour countries have kindly donated computer hardware and software to various government departments and institutions. Quite often, these products are **not compatible** which makes an information transfer impossible.

The mentioned use of **different spheroids and projections** created an enormous amount of additional work because it was not always possible to transfer differently digitised maps to the other grid system.

5.0 Recommendations

Before starting an inventory related to nationwide forest cover, the legal ***definition of forest*** should exist.

Within the Management Services Division of the Forestry Department, several technical and financing projects are working harmoniously together. This was possible because all experts form an integral part of the Division and Department of Forestry. In the future, more emphasis should be put into project planning to be aware of ***full integration in the administration,*** rather than creating an own independent project infrastructure outside the administration.

It is necessary to get an agreement from the satellite data distributing agencies to ***share data*** between different government departments. Such an agreement has been reached with EOSAT for Landsat data, but it is also necessary for digital SPOT images.

Cloud cover will be a continual problem in South Pacific countries until a break through in space borne radar data. It will be an important step to have a ***Mobile ground station*** able to receive Landsat TM, SPOT and ERS-1 data.

Forest mapping which includes forest stratification is a complicated issue in the South Pacific. It requires the ***involvement of local foresters.*** Therefore satellite data analysis should be carried out in the Forestry Department, which makes it necessary to provide necessary hardware, software and training.

However, the Forestry Department will not be able to update this modern technology and will be incapable of carrying out all its own maintenance. This could be shared with a regional organization in the South Pacific, as SOPAC[4] is doing this. Such an organization should be extended to a ***regional centre*** for central data register and for performing jobs such as high quality image output, which requires expensive hardware.

[4] SOPAC = South Pacific Applied Geoscience Commission

SIX YEARS OF EXPERIENCE IN THE USE OF GEOGRAPHIC INFORMATION DERIVED FROM HIGH RESOLUTION REMOTE SENSING DATA IN THE ISLANDS OF FRENCH POLYNESIA

by

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1.0 Introduction: some basic needs in 1988-1989

When addressing the management of land and marine resources and environments, one key requirement is that all data collected and all decisions enforced are geographically registered in one single consistent process. Therefore, beyond the all important elaborate academic studies and models, one needs to collect and process georeferenced data at a scale commensurate to that of the final resources and environment management and planning documents. Like everywhere else in the Pacific islands, costly field and aerial photographic surveys have been extensively used in French Polynesia on a case-by-case basis; vast expanses of the environment have been left virtually unmanaged for lack of human and budgetary resources, at a time when remoteness is not any longer efficiently protecting any given area from potentially devastating "development" undertakings fuelled by ever burgeoning population and technology.

In the particular case of the production of modern base maps for these remote reefal areas, the difficulties are overwhelming when it comes to establishing a proper geodetic network around a large atoll, collecting cloud-free aerial photographs so far away from a proper airport, mosaiking hundreds of photographs, and thoroughly surveying water depth among coral reefs.

As of 1988, there were over 84 atolls in the Tuamotu archipelago in French Polynesia, however, modern topographic maps for land areas of only 9 atolls were available at the scale of 1:25,000 or 1:50,000. For the other 75 atolls, the only available maps were nautical charts, many of them at the scale of 1:175,000, showing the rough shape of each island and details only where useful to large merchant ships. This made it virtually impossible for managers to undertake proper management of land and marine resources and environment at a time when black pearl farming and then tourism industries started blooming in those atolls.

The availability of multispectral images in digital form shot from space by Landsat (1972 then 1979) and then SPOT (1986) earth observation satellites have changed all that. Indeed, state of the art base maps of both the shallow waters and lands in previously unchartered areas can now be prepared in digital form by computer aided processes at scales of 1:50,000 to 1:25,000. This production only requires minimum field surveys using a hand-held Global Positioning System receiver (GPS) in order to position a few remarkable land features for map registration purpose with a precision of 20 m on the ground, and a few shallow water depth soundings for final calibration of the bathymetric model down to 15-25 m.

2.0 Some advantage of satellite images and computer aided mapping

Landsat earth observation satellite images have been in use for the last 32 years, so this technology is nothing new actually.

But in 1986, SPOT added a considerable thrust to this business, as this satellite system gained very much versatility while raising the spatial resolution from 30 to 20 m, by concentrating on the three most popular spectral bands and even adding one 10 m resolution panchromatic band that can be combined

with multispectral bands to bring the spatial resolution to 10 m. This now allows for base maps and thematic maps to be prepared at a scale ranging from 1:50,000 to 1:25,000 that is adequate for most land and marine resources and environment management activities. Since then, other earth observation satellites have followed suite in Japan, in India and in China.

The launching of SPOT coincided with the personal computer and workstation revolution that now allows anyone to think of introducing RS in the workplace.

Moreover, the RS revolution and the personnal computer revolution have in turn triggered the GIS revolution. This was timely indeed, as the need to assess and manage land and marine resources and environment on a comprehensive basis can only be addressed by putting together systematic, multilayer and compatible databases describing all aspects of the areas to be managed.

Satellite data exists or is easily acquired:	*Other people get the data for you.*
Satellite data is easy to update through time:	*Good for monitoring changes.*
Quality standard of satellite data is stable through time and space:	*Good for a long-term project.* *Good for a national archive.*
Geometric quality of SPOT images is excellent:	*Good for topographic mapping.* *Scales 1:50,000 to 1:25,000.*
One satellite image provides large coverage:	*No more mosaicking for one single atoll.*
One satellite image allows for a great variety of thematic studies on land and down to 20 m water depth:	*Good for multi-users community.*
Provided existing modern map or a minimum field data is available for image registration, satellite images make it easy to derive geographic information, even over uncharted areas:	*Good for space topographic mapping.* *Good for planning purposes.*

We all know that SPT was established in 1988 straight after SPOT was launched. Of course, the purpose was not to demonstrate the quality of Landsat data.

3.0 Various methods and products at SPT

Following is a rapid review of the sequence of processings at SPT.

3.1 Geometrical correction to UTM projection

Satellite images at SPT are purchased in raw satellite projection. Therefore, they first have to be transformed to UTM projection on WGS84 ellipsoid. This is done through a physical model using orbital parameters, without any ground control points. This is particularly interesting where no such control points are available as in uncharted areas, where existing maps are too old, or prior to a field survey: the image is now a non-registered UTM map.

At this stage, the image has also been used as a base map upon which to mosaic a set of aerial photographs, in the case of the preparation of the topographic map of Mataiva: this saved the high cost of a complete preliminary geodetic survey of the island to place ground control points for the purpose of mosaicking.

Geographical registration of the image to the UTM grid is then done by use of a few ground control points corresponding to remarkable pixels that have been accurately GPS positioned in situ.

3.2 "Marine lease" base map of an atoll

Whether geographically registered or not, a colour paper copy of the corrected image at the scale of 1:50,000 to 1:25,000 is the first output, easy to produce with minimum manpower:

(a) Deep waters are made white;

(b) A dot line follows approximately 15-20 m water depth (visibility limit of sea bottom for the green channel);

(c) Full colour image is shown from approximately 4-5 m water depth (visibility limit of sea bottom for red channel) to dryland;

(d) Shallow waters and dryland colours are enhanced separately for best rendition;

(e) A cellular alphanumeric grid is overlaid;

(f) Eventually the UTM grid is added, if GCP data are available.

But, then, the users must make their own interpretation of the picture, which is not always easy.

3.3 Bathymetric model of shallow waters in lagoon, and satellite image of the sea bottom as if there was no water

For waters down to 15-25 m, depending on the water clarity and on the height of the sun, SPT can now compute a bathymetric model, even in the absence of any field data, as the satellite image contains enough information for full autocalibration of the method. This new method by SPT is being fully evaluated by the French hydrographic office (SHOM) at present and has not been published yet.

Water depths are computed in decimeters. From 0 to 3-6 m, depending on the brightness of the bottom and month in the year, the relative standard deviation is +/–0.18 m; further down, where only green channel provides information, water depth over darker bottoms like coral mounds is computed up to 4 m in excess of true depth.

The bathymetric model may now be made into bathymetric contour lines with a spacing of 1 m, ready to be loaded into a GIS.

As a most valuable by-product, a normalized image of lagoon bottom reflectance is also computed, mostly as if there were no water, down to 3-6 m of water depth. This will soon become an invaluable tool for lagoon biomass assessment projects.

3.4 "Pacific standard" basemap of an atoll

Now, it is desirable to distribute to the public a base map at the sacle of 1:50,000 to 1:25,000, derived from the satellite image. In this product, the interpretation is shown, and the data is reduced to lines and patterns. Due to the necessity of adapting standard norms of topographic maps to the realities of a space map, the product was christened "Pacific standard space map". See the prototype map for the atoll of Manihi, of which 1,000 copies were printed in four colours three years ago.

This prototype soon displayed its many flaws. Since then, much effort has been devoted to improving that product and present an extensively revised new prototype for the Pacific standard space map.

Limits are now to be hand-drawn through a computer aided photo-interpretation process by a cartographer: no more thresholding by computer specialists, which does not yield the desired limits. It did take all these years to get cartographers to consider that this actually is what they want to and can safely do:

(a) Contour of the clouds;

(b) Limit of densely vegetated areas;

(c) Limit of motus;

(d) Limit of usual high tide (the "coastline"), which often wanders at some distance from the nearest motu in areas where cyclones and tropical storms wash everything out once in a while;

(e) Limit of the usual low tide, which may be at some distance from the coastline in very flat areas;

(f) Bathymetric contour lines (5, 10, 15, and if water is very clear 20 m or even 25 m.

Those limits are then properly smoothed (not a trivial thing to do), and made into vector formated computer files ready for loading into a GIS. Lines may be thick or thin, dashes or dots. Patterns are used to fill certain domains like vegetated areas or clouds. That finishing work is still underway.

A black and white version of that map must now be produced on mylar film, for dyeline copies to be distributed at low cost to the public: never more 1,000 copies of the expensive four colours map of a remote island, most of which will have no customer at all for a few decades.

That mylar output is simply to be discarded and replaced by a new one should additional information become available, such as village map toponymy, deep water bathymetry.

3.5 Digital base maps for use in a GIS

All limits and contour lines in digital format for 27 atolls make up the digital base map for use by the Government's Sea and Aquaculture Service (SMA) in a marine lease geographic database named SIGMA POE RAVA. This production was co-financed by the European Development Fund. More on this in another talk.

In the near future, the whole "Pacific standard space map" project for over fifty atolls is to be managed with a GIS, in the hands of professional cartographers of the Town Planning Service, with assistance by SPT's computer specialists.

3.6 Nautical spacechart of atolls

This application should be presented by the Hydrographic Office (SHOM). Spatiopreparation of their field surveys is done at SPT by SHOM agents. Then integration and production of the nautical charts is done in mainland France.

3.7 Vegetation

Based on current practice, several applications have been recently investigated regarding vegetation, using existing SPOT images that date back to 1986 in many cases and therefore serve as a reference in time when compared with recent images:

(a) *General status of vegetation on very remote islands,* with a view to nature's conservation versus threats such as wild goats grazing or cyclone damage; this is easy and cheap work and needs images at different dates for monitoring purposes;

(b) *General status of natural spaces* for the six main islands most endangered by development. The aim is to map various categories of natural spaces so that remarkable areas will be properly managed and protected: the basic zoning work will be conducted using existing SPOT images together with digital terrain models (DTM); then detailed information will be added from aerial photographs and field surveys.

(c) *Inventory of vegetation in atolls.* Areal coverage and status of coconut tree groves in tens of scattered atolls are virtually unknown; moreover, agricultural aptitude of soils is unmapped. In SPOT images, wild bush vegetation, including derelict groves, is quite easily distinguished from manicured areas including cultivated coconut tree groves:

— *In wild areas,* intensity of vegetation is easily mapped, pointing to particular areas which might be worth cultivating;

— *In cultivated areas,* the white coral soils between plants is quite often baren, whatever the plantation; this does not allow for reliable maping of coconut tree groves which are not always so dense that the white soil would be masked to the satellite.

(d) *Pine forest inventory:* this was a most successful study. Various plantations can be mapped besides pine forests. This will be extended to the inventory of all existing forests, as well as to locating best potential sites for new plantations.

3.8 Various products

DTM: the digital terrain model (DTM) for the main island of Tahiti Nui has been prepared in France from a stereo pair of SPOT XS images; spatial resolution is 20 m. That was far cheaper than digitising the existing topographic maps, more because there is a copyright on such maps:

— **Education**: various products are being contributed for the production of teaching material for use in classrooms, mostly in the form of colour slides and overheads showing islands as seen from space.

— **Curios**: posters have also been produced, as well as postcards and stamps for sale to the public.

4.0 Discussion

4.1 The future of SPT

After considerable hesitation, the government decided last June to continue SPT. IFREMER will hand over the management of SPT to the government, but they have pledged to remain a major partner by providing technical support and conducting their own research programmes at SPT, mainly centred on the use of GIS technology for the management of coastal environment and resources. SPT would not be subsidised anymore, but rather should operate on some kind of semi-private basis.

A review of expected activities is being conducted under the authority of the Minister for Research; it covers a wide range of applications for the next five to ten years:

(a) Clearly, it is expected that SPT should maintain a satellite image database for the local community;

(b) *Systematic production of base maps in digital form* for over fifty atolls is quite certain, including bathymetric models. This will have to be managed with a GIS;

(c) *Applications on pine forest inventory and on vegetation in the atolls* will be developed;

(d) The applications of *SIGMA POE RAVA will be extended* to other activities, such as management of forestry and of land areas in atolls, and also to the computation of marine lease taxes;

(e) *Hydrographers will probably continue* to do their spatiopreparation work prior to their field surveys;

(f) A series of *products for educational purposes* will be produced, and there is a request for SPT to handle a training programme in RS and GIS for teachers;

(g) *In the GIS arena, clearly SPT* will have to play a major role in the process of getting the government services linked through;

(h) One last task will be to run and maintain the *database of EEZ* mapping data.

4.2 Some hot issues

Now, in view of the forthcoming working group meetings to formulate a Pacific subregional action plan, we may ask whether these technologies have actually found their way in Tahiti to the very workplaces where we figure they ought to be put to good use after six years of hard pioneering work.

This question points to several hot issues, many of which are related to the difficulty for a professional of embracing a completely new way of doing the same things he does with aerial photographs, and may result in the first generation final products being eventually rejected.

FOUR YEARS OF EXPERIENCE IN INTEGRATING AND USING RS DATA WITH ADMINISTRATIVE DATA IN A SMALL GIS FOR THE MANAGEMENT OF PEARL FARMING ACTIVITIES IN FRENCH POLYNESIA

by

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1.0 Introduction: basic needs in 1988-1989

In the years 1985-1990, a considerable boom was experienced in the pearl farming activities in the atolls of the Tuamotu archipelago, fuelled by massive financial aid distributed to the population soon after a series of cyclones wrecked the coconut trees plantations.

Thousands of application dossiers for grant of marine leases were submitted within five years. Quite often, applicants wanted new leases in areas in which existing farms extended their structures far away from the limits of granted lease.

In 1985, severe mortality in existing pearl farms pointed to the urgent necessity to undertake proper if not drastic management practices in some overdevelopped lagoons. Metallic tubing structures were banned, and farmers deployed instead extensive floating cable structures that use existing coral heads. The actual area covered by each farm then became anyone's guess, as many farms were relocated and extended among coral heads. Unit areal coverage used to be by the 1,000 sqm; now it is by the hectare.

The situation called for urgent measures to be taken, with regard to both lagoon space and administrative leases management, that would result in:

(a) A fair and timely processing of new applications;
(b) An equitable taxation system based on real space occupation;
(c) An proper knowledge database for biomass control in tens of lagoons.

Therefore, a field control programme was established in 1986 by the Sea and Aquaculture Service (SMA). This programme first focused on four of the most densely farmed atolls for which existing topographic maps could be enlarged to the scale of 1:10,000. Field control data were hand plotted on several-meter-long enlarged copies of these maps, a cumbersome process that took several months per survey.

Then this programme was fully stalled when it came to atolls for which no map existed at a proper scale, as there was no money to pay for aerial photographic surveys and the preparation of proper topographic maps.

2.0 Basic specifications of the information system

2.1 In that situation, the need was dual

(a) *Paper base maps for over 30 atolls* for use by SMA agents for planning and then conducting their field control surveys, and for use by new applicants in their application dossiers; hence the name "marine lease spacemap"; a complete description of the lagoon structures inside

the lagoon is required, as the coral heads are now so important to pearl farmers and to new applicants;

(b) *Digital basemaps and a computer database* management system with geographical capabilities with which to expedite the processing of:

— Field survey control data along with the basic marine lease administrative dossiers on the one hand;

— And of several hundreds of application dossiers per year on the other hand.

As the preparation of marine lease spacemaps was described previously, we will focus on the preparation of digital basemaps and on the information system.

SIGMA POE RAVA stands for Geographic Information System Sea and Aquaculture for Black Pearl (poe rava). It is composed of a graphic database that contains some 30 digital basemaps, and an alphanumeric database that contains administrative data describing application dossiers and field control data for thousands of leases.

In order to reduce its costs and to facilitate its installation and its use on a long term basis both in-house and in the field by SMA's non computer-oriented staff, this GIS was developped in a multiuser PC environment. It uses the CAD package Microstation Intergraph that allows the generation of graphic base maps and linking these with the alphanumeric data.

3.0 Integrating data in the GIS

3.1 Digital base map

3.1.1 Geometrical correction to UTM projection and grid

UTM projection of the satellite image was exposed elsewhere.

3.1.2 Extraction of contours

The digital base maps were to provide the geographic framework of the database. The most important features were the position of the coral heads and the water depth ranges. After separating the ocean, the lagoon and the dryland, five contours are extracted by computer specialists using simple thresholding computer processes:

(a) A contour of densely vegetated area; in this process, poorly vegetated areas are considered vegetated area, and distinguishing these two components would require much manual finishing. This contour is certainly not to be confused with a "coastline" or a "limit of motus";

(b) A contour of the limit of the sea. This very much depends on the tide at the time the image was shot, and there is no attempt here to draw a real low or high tide contour Again, this contour is certainly not to be confused with a "coastline" or a "limit of motus";

(c) A contour of water depth approximately 4 to 5 meters, beyond which the lagoon bottom is not visible anymore in the red channel of the satellite image;

(d) A contour of water depth approximately 15 to 20 meters, beyond which the lagoon bottom is not visible anymore in the green channel of the satellite image. These two contours are of great interest to farmers;

(e) Finally, contours of clouds are drawn manually.

In this process, all coral heads any larger than 20 m in diameter are fully accounted for. This is of great interest to both farmers and SMA for two reasons: firstly, the coral heads are used as strongholds

from which to array farming cable structures; secondly, they are places where the biomass productivity is natural fostered.

Acreage of the lagoon, of the dryland, and of various depth ranges are then computed.

Then, those contours are converted from image files to vector files, so that they can be loaded into the GIS. That information is now reduced to points, lines, and polygons into handy small volume graphic files, each with its attribute describing the name of the island and the nature of the information.

3.1.3 UTM grid registration, and alphanumeric grid system

This is of utmost importance as it allows all field control data to be positionned in UTM coordinates relative to existing coral heads and general set-up of land features.

The base map is registered to the UTM grid by use of a set of remarquable ground control points (GCP). These are specific proeminent pixels of the satellite image that have been visited in the field and positioned by way of a GPS receiver. Practically, five to ten ground control points are used, just to allow for discarding some of them, as several years may have passed since the image was shot and the local environment may have changed, and also as each GPS position may be misplaced by up to 100 m in single mode GPS.

Then, a UTM grid is generated and overlayed onto the base map. An alphanumeric grid is also overlayed, that allows for locating a given lease by the 1 by 1 km cell on the ground such as R23, B14.

3.2 Alphanumeric data

All data is collected by SMA staff. They are administrative lease dossiers and field control data.

Administrative lease dossiers contain information on the identity of the lessee, the location, area, details of requested lease and of granted lease, and the decision by the Marine Lease Commission.

3.2.1 Field control data are diversified

(a) *For each farm:* data on the location and description of each component of the farm, material used, number of oysters on each line etc;

(b) *For each atoll:* data on general setting, such as number of inhabitants, sea or road links, names of places, location of ground control points;

(c) *Additional* alphanumeric data such as toponymy.

In the field, controllers fill in forms detailing the result of their work. Back in the office, all this field information is then keyed in a matter of weeks.

3.3 Use of the system

From all these parameters, it is now possible to querry the database, for example, to ask for all structures deployed by one given lesses, and display the result of the querry on the graphic screen or with a plotter along with the base map.

It is now possible to manage marine leases in a most equitable and timely manner by:

(a) Comparing the granted polygon with the area actually used by each lessee, and proposing necessary adjustments for decision by the marine lease commission, particularly in view of the calculation of taxes to be paid;

(b) Locating areas where there is still enough space for granting new leases to numerous and eager applicants.

3.4 Description of the information system

The system uses functionalities of the Microstation toolbox like displaying 63 different levels of drawing, calling for external drawing files, ... The various elements of the database are ordered in a way that facilitates data manipulation and querry.

Specific tools have been developed, such as a map registration tool, several data entry worksheets, various statistical tools, various database report formats.

One may visualize graphical elements such as one given island, one given farm, all sites requested by one given applicant, all oyster breed structures in the lagoon, all leases in a given grid cell or close to a given site name, etc.

Therefore, the user only manipulates graphical elements and can rapidly access the caracteristics of any element such as the name of the owner, the area farmed, the number of oysters cultivated, etc.

3.5 Short and long term perspectives

3.5.1 Short term evoluation of SIGAM Poe Rava

During the last four years two important events occurred:

(a) *Major change in the field control programme:* after being stalled for two years for geopolitical reasons, the whole field control programme at SMA was resumed in 1994 to focus on controlling only the polygons occupied by farmers instead of the detail of structures contained in those polygons. For the most densely farmed areas of certain atolls where the problems are most urgent, this is presently being done by heavy geodetic field surveys followed by aerial photography and manual processing. This is a quick but very costly process, that is only acceptable where the costs can be shared with the Land Use Service, and will most probably not be applied to less urgent areas or islands for a long time. Digital base maps at the scale of 1:5,000 are being derived from those surveys that replace locally part of the base maps derived from satellite image for the atolls concerned, those local additions are received in the database without any difficulty;

(b) *A new requirement for contours of the motus:* upon using the prototype database for four years, the Marine Lease Commission started using the computer base maps as if they were truly detailed land use maps in order to match applications with existing or supposed properties, as any owner is entitled to a marine lease opposite his property. Indeed, there is virtually no proper land use map available for many atolls and those that exist are not in modern topographic standard, do not show coral heads, and have not been digitised. In 1993, the Ministry of the Sea pointed out that motus are missing in base maps prepared by SPT, and declared it would not pay for the 27 base maps they and ordered;

In recent years the Marine Lease Commission has been able to see things as they really are in the field for the four atolls loaded in the prototype SIGMA in 1991. Therefore, they quite naturally started wanting more from the system than what it had actually been designed for. Indeed, the areas most densely farmed are now managed at a scale of 1:5,000 with the precision of 1 m on the ground, whereas the problems to be solved six years ago required only a precision of 100 m on the ground for which the scale of 1:50,000 was adequate enough;

Another and more serious problem was the fact that, from the very begining, cartographers at the Town Planning Service did not really consider contributing in a constructive manner to SPT's pioneer efforts in using satellite images to make the maps that they had to produce

when they could not get a hold of aerial photographs. Instead, they managed to regain their chances of getting aerial photographs by highlighting the flaws of SPT maps;

Finally, as the career of the head of the topographic section drew to an end, a geologist at SPT proposed in 1994 a better way of reducing the image data manually by a computer aided manual photointerpretation process instead of automatic thresholding by computer specialists. The protocol for doing that is presently being finalised and will soon be officially issued by the Town Planning Service;

This official protocol will allow SMA to put out an administrative order for SPT to prepare and deliver in 1995 27 files describing the contours of motus from satellite images, and the Ministry to express satisfaction so that the EU in Suva finally pays their contribution. The contour of the motus will then be loaded into SIGMA POE RAVA, wandering at irregular distance from both the contour of densely vegetated areas and the limit of the water.

(c) *Implementation:* after being used by SMA as a stand alone prototype for four years, the system was fully implemented last november, thanks to the co-financing by the European Union. It is now comprised of a network of four PC workstations, including one portable unit that can be taken in the field, with A4/A3 pen plotter. The equipment was installed together with the multiuser version of the software developped at SPT and 27 ditital base maps derived from satellite images.

BATHYMETRIC MODELLING OF LAGOONS USING REMOTE SENSING DATA: NEW RESULTS AND PERSPECTIVES

by

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Following work by Loubersac (IFREMER, 1987-1988), Georgery (SHOM, 1991) and Maritorena (UFP, 1993), the theory of optical model in lagoonal waters has been used to develop an operational process for the production of bathymetric models. This process is fast and quite precise within water depths 0 to 3-6 m. This was made possible thanks to an outstanding set of bathymetric lines collected in various parts of the lagoon of the island of Moorea, French Polynesia. Using the SPOT XS image of any lagoon and even in the absence of any field data, SPT can now compute an image of the lagoon bottom normalized reflectance down to 3-6 m, and an autocalibrated bathymetric model of waters down to 15 to 20-25 m, depending on bottom reflectance, water clarity and height of the sun.

These performances are based on the analysis of two samples of pixels chosen to represent:

(a) The various substrates on baren dryland, from which a model is derived for seabottom reflectance as if there was no water; this method allows for normalizing the brightness into reflectance between that of the ubiquitous brightest coral sands or rubbles and that of the dark deep lagoonal water.

(b) The brightest submerged sands: this is used to measure the value of the ratio k1/k2 of the light attenuation coefficients in water for channels XS1 and XS2 of SPOT. Having measured this value, one can calibrate the radiometry of any submerged pixel by its counterpart on barren dryland with the same brightness. The process also uses the very strong correlation observed between k1 and k2 by Maritorena in 21 radiometric measurement field stations of the lagoons of Moorea and Takapoto: having measured k1/k2, one can therefore derive a very good approximation of k1; kl is given in percents of light attenuation by meter of water depth.

In these conditions, even with no field data available, the autocalibration of the process is complete as results are directly computed in decimeters of water depth from 0 down to 15-25 m. Over ten parameters are used in one single computer run. Where the lagoon bottom is visible by both channels XS1 and XS2 (from 0 to 3-6 m), the results are fully corrected of the influence of variation of lagoon bottom reflectance; but where the bottom is only visible by channel XS1 (further down to 15-25 m), one can only use a value of lagoon bottom reflectance supposedly representative of that of the most frequent lagoon bottom, namely that of bright sand or ooze.

In the case of the lagoon of Temae at Moorea, the standard deviation is +/–0, 18 m for a mean depth of 2 m from fringing reef to reef crest. This error seems to be mostly due to the lack of precision of the baren dryland radiometric model used to represent the radiometry of submerged pixels.

In the SPOT image of Temae lagoon shot in July 1986, the error does reach +/–0, 8 m for local patches of adjacent lagoon pixels where the lagoon bottom seems to have been more green or more red than the model used at that time. If subsequent multitemporal studies can show that some of those patches are not stable through time, then the errors in the bathymetric model could possibly by measured, corrected, and used to map such probable temporary developments of those greenish or reddish patches.

From 3-6 m to 15-25 m, the computed depth may be locally 2 to 4 m in excess of true depth where the bottom is living coral or algae rather than bright sand or ooze.

The final results are a digital terrain model of the lagoon bottom down to 15-25 m, and an image map of the lagoon bottom normalized reflectance down to 3-6 m. Full validation of this new method is to be carried on in March-June this year in collaboration with SHOM. Then, the following activities may be planned:

(a) Undertake the systematic production of bathymetric models down to 15-25 m and of maps of the normalized seabottom reflectance down to 3-6 m, even where no field data is available.

(b) Further the research by:

  (i) Conducting atmospheric corrections;

  (ii) Using a blue channel (like Landsat TM1) to improve the precision of the result down to 15-20 m;

  (iii) Using panchromatic channel to improve the spatial resolution;

  (iv) Using channel XS3 to improve the modelisation of very shallow waters,

  (v) Detailing the radiometric model of baren dryland;

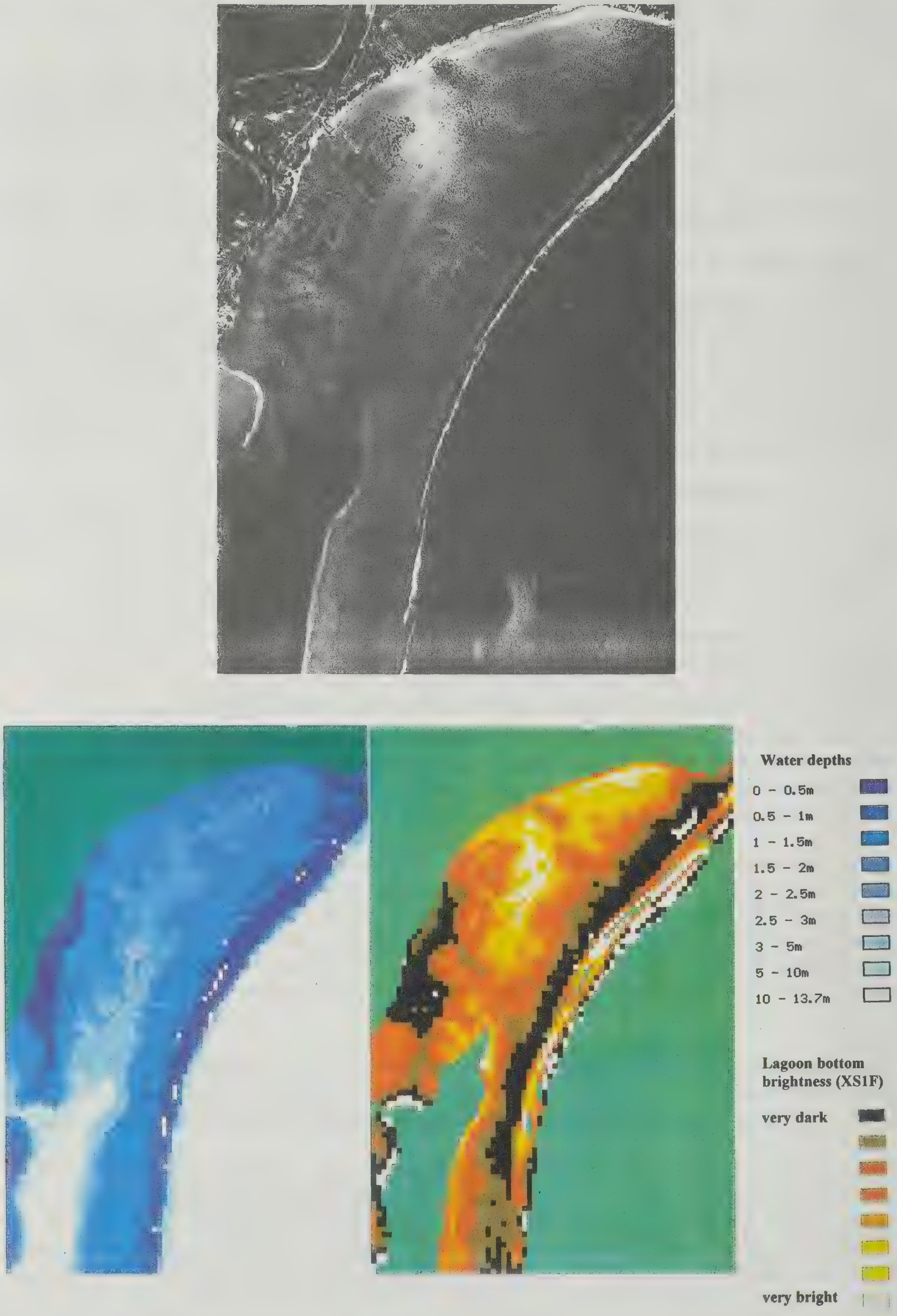
  (vi) Investigating the use of digitized aerial photographs for bathymetric modelling in order to lower the spatial resolution from 20 to 1 meter.

(c) Develop cooperative thematic research programmes on:

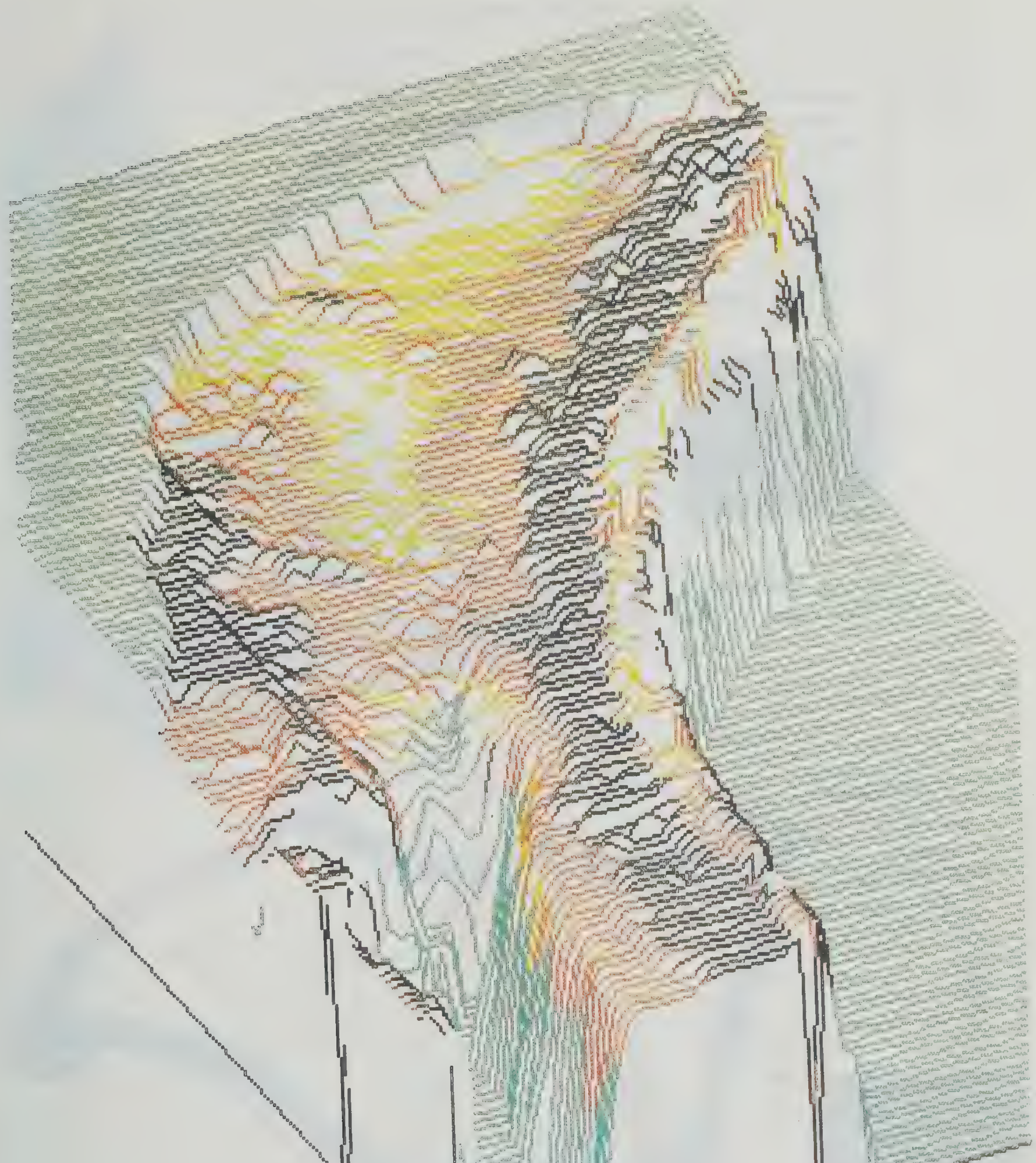
  (i) Development of the rules of qualitative and quantitative interpretation of the normalized image map of the lagoon bottom;

  (ii) Multitemporal studies of seasonal variations of lagoonal biotopes;

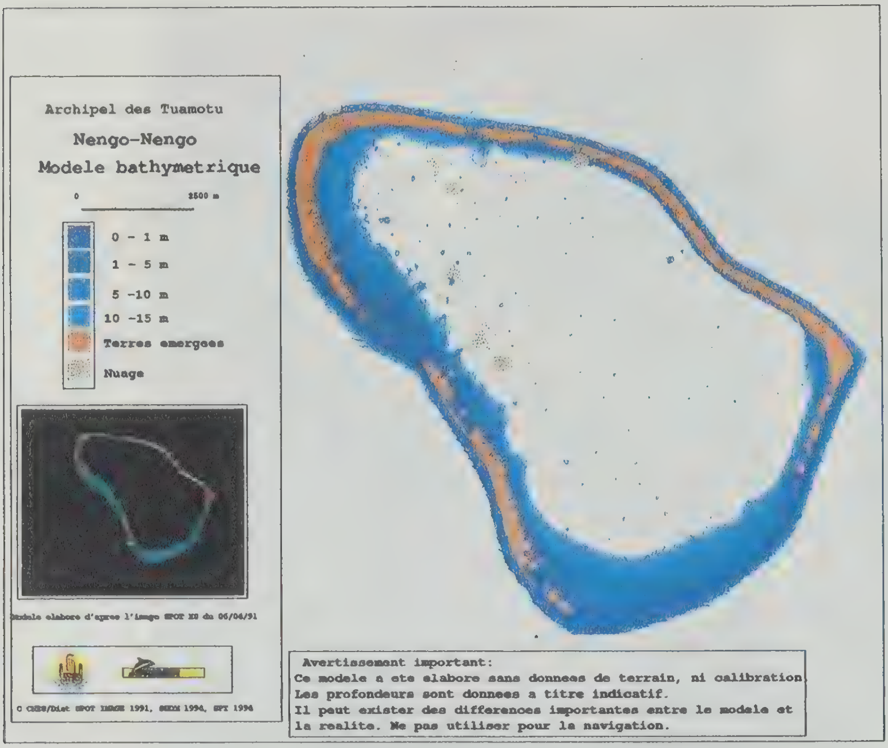
  (iii) Study of the determinism of the radiometric signal received by the satellite from a lagoon's deep waters as a function of its local hydrological condition. Such a study might prove valuable for the management of lagoon biomass and for the understanding of the endo-upwelling process.



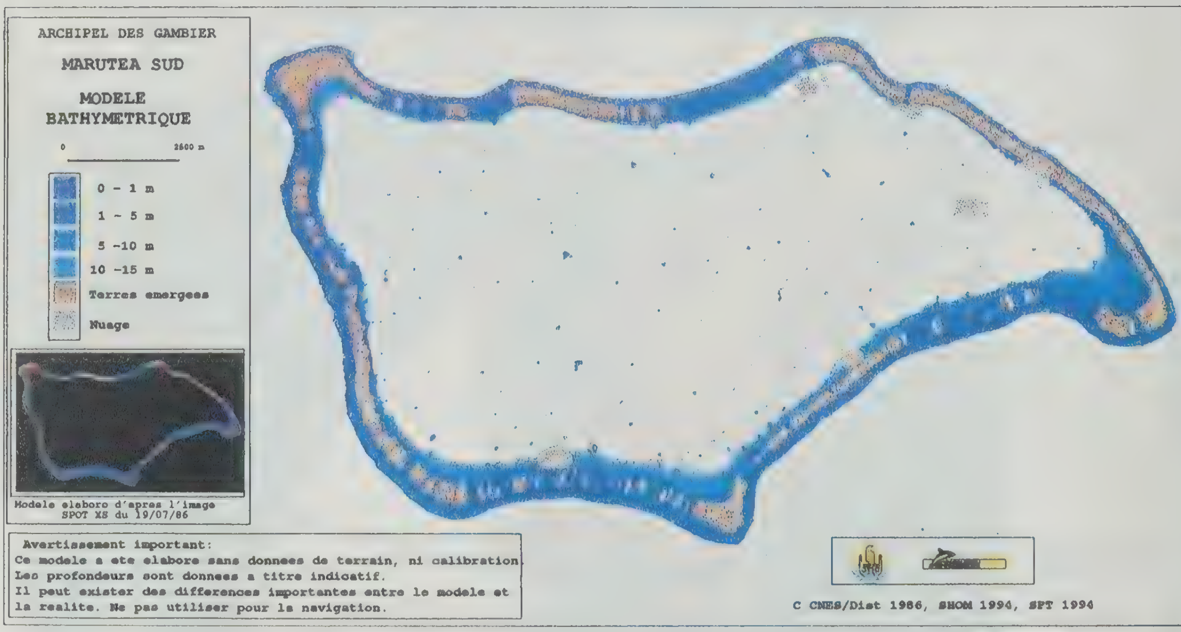
Bathymetric model of Temae lagoon, Moorea, French Polynesia



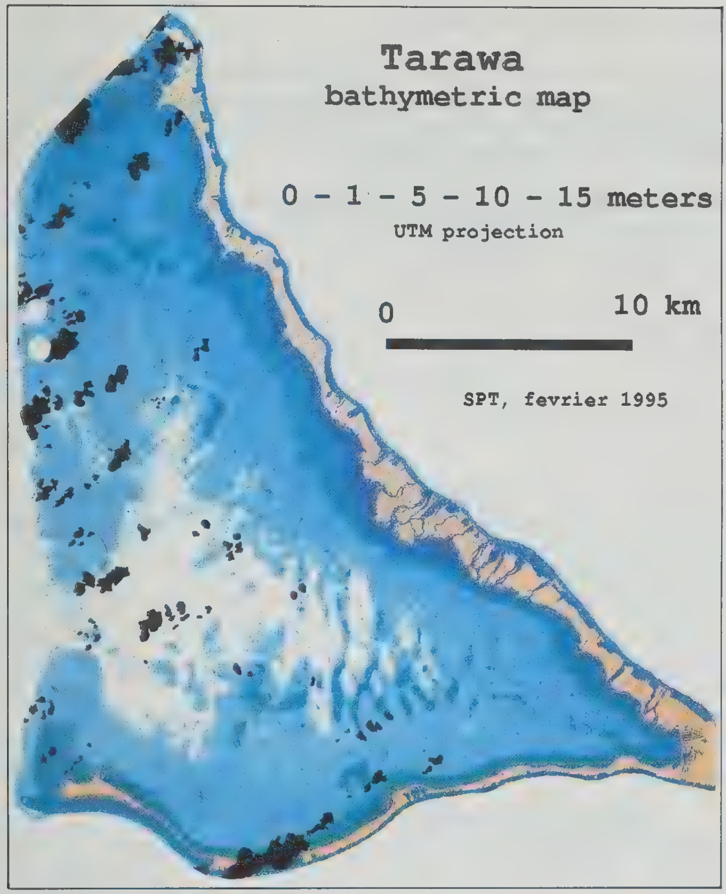
3D view of bathymetric model of Temae lagoon with bottom brightness overlay

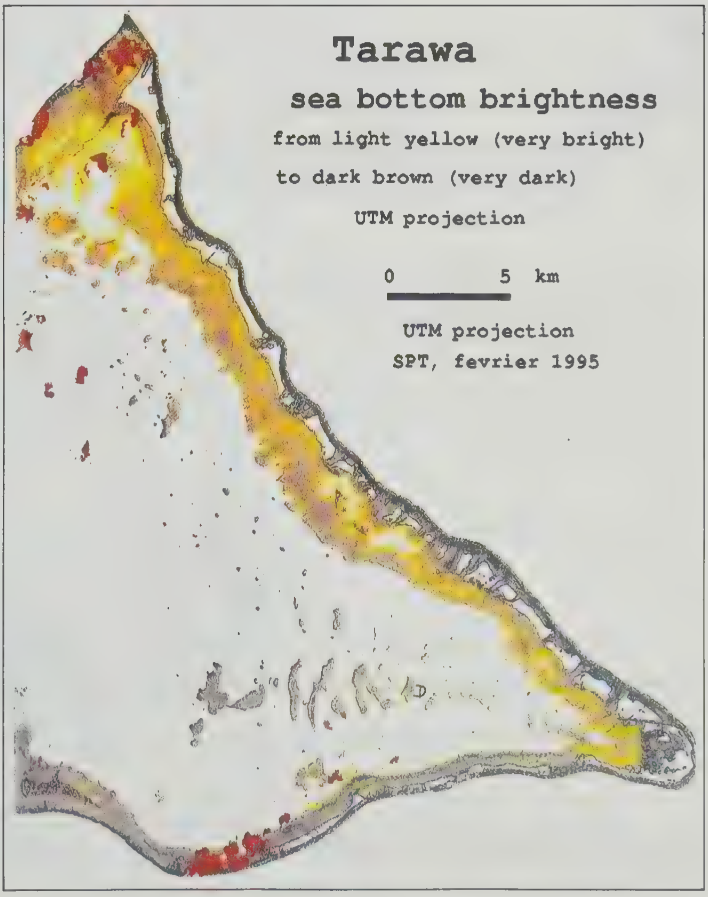


Archipel des Tuamotu
Nengo-Nengo
Modele bathymetrique
0 2500 m
0 - 1 m
1 - 5 m
5 -10 m
10 -15 m
Terres emergees
Nuage
Modele elabore d'apres l'image SPOT XS du 06/04/91
C CNES/Dist SPOT IMAGE 1991, SHOM 1994, SPT 1994
Avertissement important:
Ce modele a ete elabore sans donnees de terrain, ni calibration.
Les profondeurs sont donnees a titre indicatif.
Il peut exister des differences importantes entre le modele et la realite. Ne pas utiliser pour la navigation.



ARCHIPEL DES GAMBIER
MARUTEA SUD
MODELE BATHYMETRIQUE
0 2500 m
0 - 1 m
1 - 5 m
5 -10 m
10 -15 m
Terres emergees
Nuage
Modele elaboro d'apres l'image SPOT XS du 19/07/86
Avertissement important:
Ce modele a ete elabore sans donnees de terrain, ni calibration.
Les profondeurs sont donnees a titre indicatif.
Il peut exister des differences importantes entre le modele et la realite. Ne pas utiliser pour la navigation.
C CNES/Dist 1986, SHOM 1994, SPT 1994

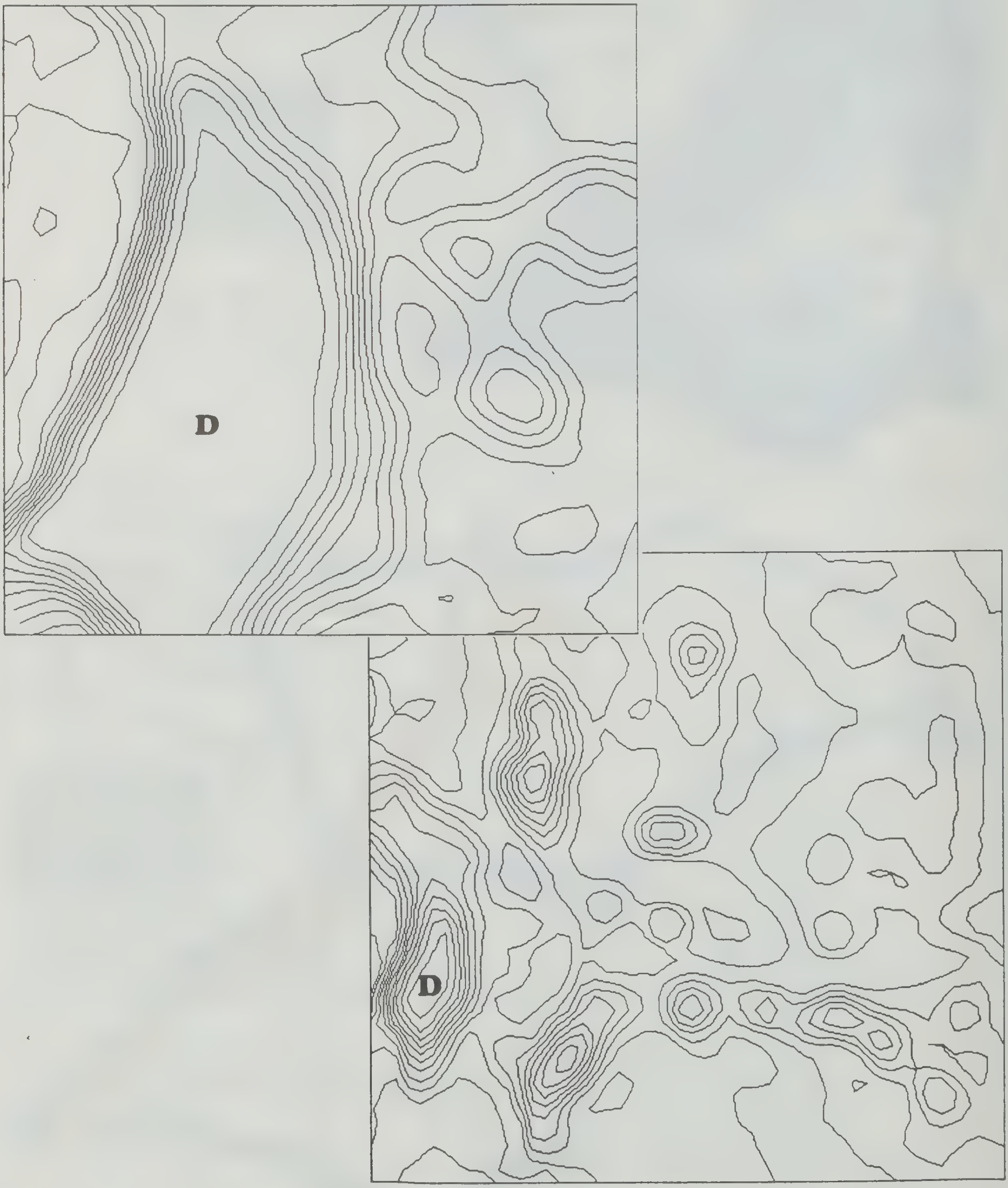

Tarawa
bathymetric map
0 - 1 - 5 - 10 - 15 meters
UTM projection
0
10 km
SPT, fevrier 1995


Tarawa
sea bottom brightness
from light yellow (very bright)
to dark brown (very dark)
UTM projection
0
5 km
UTM projection
SPT, fevrier 1995

Bathymetric map of Tarawa lagoon

The bathymetric model was prepared at SPT in January 1995 from SPOT XS image shot 20/7/1988 without using any field data. Bathymetric contour lines were computed from the bathymetric model through a strong smoothing operator in order to smooth out the 2-4 m gap on the western dark bottomed slope; their spacing is 1 meter; they are formated in a vector computer file and can therefore be loaded in a vector geographic information system. Tide is estimated 1.5 m high.

See location of the main hydraulic dune on the map showing the brightness of sea bottom, signaled by a black "D". The flat top of that dune is around 1.5 meter deep; that dune stands 11 m over the surrounding lagoon bottom. Its western slope seems to be far steeper and also far darker than its eastern slope. These samples are 1 and 4 km wide.



IMPLEMENTATION OF GIS FOR LAND MANAGEMENT IN FRENCH POLYNESIA. TWO EXAMPLES: THE MAKING OF DEVELOPMENT PLANS-QUANTIFICATION OF A COAST LINE

by

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1.0 Introduction

The Etudes et Plans section of the Service de l'Urbanisme has been asked to make the Schéma d'Aménagement Général et d'Equipement of French Polynesia (S.A.G.E.) and the Plans Généraux d'Aménagement of the townships (P.G.A.). The procedures and modes of arrangement of these tools of regional and local planning are provided by the Code de l'Aménagement of French Polynesia.

During the making of the P.G.A. or of S.A.G.E., the use of graphic documents is continuous:

- Study of the existing graphic documents;
- Analysis of the land;
- Knowledge of the relief;
- Definition of the first proposition of zoning;
- Corrections according to the desiderata expressed by the population or the municipal council;
- Last document.

In order to face the increasing demands of the townships of French Polynesia as to the macro and micro-development plans, the resort to a modern and high-performance graphics tool was necessary. The step of modernization could not however be limited to the simple replacement of the drawing table by the cathodic display and the "mouse". It implied a change in the way of working, a reorganization of the tasks and a union of wills and means in order to come to a real sharing of information by several services, a fortiori within a same service by several sections.

The analysis showed that the introduction of a geographic information system within the Etudes et Plans section represented the most appropriate solution. A remarkable technical progress as regards data acquisition, analysis, and graphic representation, such a system can store, share, inquire and handle represented objects on maps or plans (plots, streets, buildings, canalizations, ...) with their geometric description as well as all information that is appended to it (area of the plot, features of the building, and so on.).

However, several unknown factors remain, as is often the case when a new technology is dealt with:

- The qualification and the training of the staff;
- The cost of the material and softwares;
- The mode and the acquisition speed, and in fact, the acquisition cost of geographic data;
- The advantages that can be expected in terms of efficiency, best knowledge of the field and help as to the decision.

What means for what goals? That was the equation with several variables that deviated then in 1992.

Define reasonable goals, then a budget and delimit the necessary means was the first step. This was followed by a period of learning the materials and softwares that were bought. Finally the implementation was started with tests that allowed the finalizing of a set of methods that more than one outside observer was now performing.

The purpose of this report is to trace the history of the GIS FENUA, explain the different aspects of its implementation and to describe the two achievements that have been well made in six months. This experience should logically open one day on the creation of a geographic data bank by the French Polynesia Territory, implying the participation of territorial services and bodies called to speak of files geographically localizable (Department of Cadastre, Department of Agriculture, Department of Public Domain, Department of Environment, Department of Equipment, Department of Planning, ...) and that of the networks dealers (electricity, water, telephone).

2.0 History

2.1 First tests of GIS in French Polynesia

The necessity of an integrated management of a geographic database put at the disposal of several administrative services has been expressed for several years. The gathering of traditional plans from different parts and scales is a hard task. But, their transposition in a unique system of reference allows to compare them, to superpose, to define the similarities or the differences easily, by freeing from problems of scale.

The French Polynesia Territory has followed the first developments of the GIS in the mid-1980s and several meetings have been held between the service de l'Informatique, the Service du Cadastre, the Direction de l'Equipement and the Service de l'Urbanisme. These meetings ended in 1988 with the decision to acquir the PREFIX system by the Service de l'Informatique and the creation within this latter of "informatique technique" department composed of two computer agents who were in charge of the elaboration of a system integrating the artwork of plots, buildings etc. and of data linked to these geographic entities.

At the end of four years of fruitless work, the system was unfortunately abandoned in 1992 and the "Informatique technique" structure dissolved. But the needs that have not been met needed to be urgently resolved, because of the increasing complexity of human activities and the development of the dispute as regards administrative authorization that is the concern of the Code de l'Amenagement.

Because it was willing to pursue the research, the Service de l'Urbanisme decided to buy a less expensive GIS, more standardized, and offering better possibilities of transfers with other applications, in order to acquire know-how, scarce in Polynesia, at less risk. The legitimate fears caused by the previous disappointment disappeared progressively and the file was submitted to the Commission de l'Informatique, in charge of the examination of the validity of the computer investments of the territorial services, that approved it in May 1993.

2.2 Description of the graphic shapes existing in Polynesia in March 1992

Before selecting an equipment and software option, five services and bodies having an experience as regards graphics data processing centered on the management of geographic data have been approached during the month of March 1992.

2.2.1 Bureau d'Etudes de l'Office des Postes (Tipaerui)

The Bureau d'Études de l'Office des Postes' goal is to establish an estimated quantity (labour and materials) of the renovation and extension sites of the telephone network. This section is equipped with an IBM PC compatible central unit and of the Autocad software. By using the plans of the road

network provided with the digital form by the private surveyors, the technician graphically draws the plan of the modifying telephone network, by precising its features.

Then, the software calculates the quantity of the necessary materials (length and type of wire, electric relays and other accessories) as well as the time the site will last according to the number of team concerned.

Because of the limited length of life and of the located feature of the stored information, the system used does not really fit into the framework of a geographic information system. However, it was necessary to study it, just to evaluate the functions of the Autocad software.

It must be noted that the plans of the telephone network (aerial and underground) of the Post Office are not managed informatically.

2.2.2 Polynesian Remote Sensing Station — Service de la Mer et de l'Aquaculture

The Polynesian Remote Sensing Station is the result of a cooperation between IFREMER and the French Polynesia Territory which is represented within this structure by the Service de la Mer et de l'Aquaculture. Originally set up in order to operate the image treatment by satellite, the SPT progressively extended its skills to graphic data processing for some territorial services.

In order to meet the needs of the Service de la Mer et de l'Aquaculture with respect to the management of sea concessions for the culture of pearls, during the great increase of files in 1990, the SPT has developed geographic information system called SIGMA POE RAVA. This tool has allowed to compare the theoretical place of the granted concessions, and the surface area occupied by the petitioners. Some major differences were observed, as well at the level of the surface as at the level of location, the con-cession was considered by the citizens as an authorization that could be changed without formality.

The system installed at the SMA consists of:

- An IBM PC compatible central unit;
- An A4 laser printer;
- The Microstation software for the graphic part, database for the management of data.

The outline of the islets and karenas is provided by the SPT under a vectorial form after the treatment of SPOT satellite images. A network model of SIGMA POE RAVA is now being developed.

The functions of this model are to:

- Manage the holders of sea concessions;
- Manage the concessions applications;
- Manage the granted concessions;
- Recollect the real locations after control tasks;
- Automatic line of the locations of concessions;
- Query the database on the basis of different search criteria.

It is necessary to remind that SIGMA POE RAVA is the first GIS developed in French Polynesia.

2.2.3 Data processing service of the territory

The French Polynesia territory is represented in the few references of the COFET Informatique Society, an editor of the PREFIX software functioning on BULL SPS7 micro-computer.

Among the constraints imposed by the schedule of conditions of the time appeared the obligation to run in multiposts around a centralized system that excluded the GIS that functioned on IBM PC compatible equipment. Besides, the desire to free itself from the "subjection" implied by the position of a simple user of a package has lead the Service de l'Informatique to favour the solution of an open software that can be modulated according to the necessities of each. This philosophy, which has its advantages and disadvantages supposes that on the other side the computerist staff is a able to supply the necessary modifications.

The choice of the PREFIX product in 1988 lies on the relative scarcity of the software offer as regards geographic computer, considering the desiderata mentioned above.

The functions of the software and those of a regular CAD aid (computer aided design), with a few controls typical of the research and handling of geographic data. They are organized according to a topologic model.

The software is composed of a BULL SPS7 central unity, three alphanumeric consoles, a graphic console, a table to digitize format A0, a pen plotter format A0.

2.2.4 Town Hall of Papeete

The town Hall of Papeete was equipped in 1991 with an IBM PC compatible platform and Microstation software. The decision relative to the purchase was a consequence of the movement started by the computer service of the Territory and the SPT.

The system bought by the Town Hall of Papeete for an amount of PF 4,000,000 is composed of:

- An IBM PC compatible central unit (386-33 processor);
- A feather plotter A1;
- A table to digitize A0;
- A microstation software for the graphic part, data files.

Because there was no competent staff and adequately thorough analysis or necessary motivation the use of the material was limited during two years to a substitution of the manual tool (the drawing board) by the electronic instrument without a real management of the database. On the other hand, the absence of a renovated cadastre (being achieved) in Papeete remains a real obstacle to the coherence and reliability of a GIS. Because of this deficiency its disappearance may be justified.

2.2.5 SPEED company

This company was given the task in 1991 by the Electricité de Tahiti company, to create a management tool of the electric network of the urban zone of Tahiti (from Papenoo to Papara) in order to facilitate the location of its 50,000 consumers and the updating of aerial and underground networks plans.

A team composed of two draughtsmen responsible for the digitization and a computer engineer were trained to use the APIC software that works on SUN workstations. The rate of the digitization was sustained in two years, the entire cadastral plates of the urban zone was digitized as well as the topographic plates at 1/500 of Papeete. When no other document was available, the maps at 1/5,000 were used in order to mark out the buildings.

Because at the start its only goal was the localization of the consumers, the underground networks and the location of the electric posts or other transformers, the SPEED company did not insist on precision. The accuracy to the original documents was not considered in a perfect way, at least at first, and some differences sometimes important have been noted. Therefore, the transfer of numeric data to the GIS FENUA, has been abandoned temporarily.

The total cost of the investment rose to PF 100 millions.

3.0 Achievement of the GIS FENUA

3.1 Summary of the schedule of conditions

The GIS should allow the visualization of the graph of the plots, buildings and the fences and roads. The search of the plots should be made with cadastral references (township, section and number of plot). Besides, the knowledge of the relief is necessary as regards development, the contour lines will be superposed to the cadastral survey. A sharp sloping relief can indeed thwart the potentialities of development of some big domains.

The second implementation of the GIS will be directed towards the production of the thematic maps from statistical data coming from the general census of the population. A scale model should be done on the basis of the results of 1988 in expectation of the 1996 census.

Considering the very limited budget, the subcontracting to the private sector deprived of the digitization of the graphic data cannot be considered. The data capture and the updating of the cadastral plates will be studied as performing as possibel, because of the limitation of the data capture equipment of plans with one table to digitize.

Finally, the instruments will be linked in network, with a non-dedicated server.

The cost of the complete system should fit into an inferior budget at PF 6,000,000.

3.2 Choice of the system

Considering the expressed demands, systems that have proved economically acceptable were selected as regards the attributed budget. Besides, the possibility of easily exchanging data between users of a same software was a determining factor in the selection.

The PREFIX and Autocad systems were avoided because of lack of proof of success on the Territory as regards expressed goals, as well as the APIC system because of its cost.

Therefore the Microstation software was chosen, published by the Intergraph Company. This company controls 15 per cent of the world market of the GIS. Besides, it works on IBM Compatibles, a world of the microcomputing.

The order of the necessary equipment was launched in August 1993 for an amount of PF 5,900,000. A training of a dozen hours to the programming of the Microstation software was given in December 1993 to the employers of the Planning department (Service de l'Urbanisme), by a computer engineer of the Polynesian Remote Sensing Station.

At the beginning of February 1994, it was decided to start the first stage of the GIS FENUA, that consisted of digitizing the cadastral plans (plots, buildings, fences, roads, ...) to link each plot to a file of the database and to create the procedures of research of plots. The second phase of the GIS is a matter of the production of thematic maps according to the statistic data currently being developed and to be finished in 1995.

3.3 Implementation of the GIS FENUA and data capture

3.3.1 Digitization

This operation consists of converting the graphic information in to numbers. The map is carefully attached on the table in order to avoid any displacement or warping. Four or five reference points are

chosen on the map, and same coordinate points are created in the design file. Initialisation of the table consists of making a relationship between the points on the map and the points on the design file. This representation is vectorial, because of the point by point data capture of the summit of vectors with the magnetic mouse. It differs from the "raster" representation of the satellite images or coming from the scanner by the fact that in this last format, a straight line is not composed of only two points (summits) but of as many intermediary points (pixels) as the resolution of the equipment allows it.

3.3.2 System of projection

The projection system that allows a flat representation of the Earth used in French Polynesia since the works of the French Institut Géographique National (IGN) in 1954, is the system MTU (Mercator Transverse Universel) coupled with the international ellipsoid of reference. Its principle lies in the projection on a cylinder tangent to a meridian and divide our planet in 60 North-South zones, of a width of 660 km at the equator. The distortion is maximum at the poles, where two points that are close in reality are very far on the plan if they are located on two different zones. In the case of Polynesia, distributed on 4 zones, an entire map will be necessarily wrong, according to this system of coordinates.

All the maps of the Service de l'Urbanisme, the recent plans achieved by the Service du Cadastre and the majority of the plans of the Direction de l'Equipement are linked to this system of coordinates, thus allowing the same spotting of a point or of an object on several different documents, in the covered places by a geodesy of base.

3.3.3 Internal representation of elements of the drawing (proprietary of Intergraph Company)

The documentation of the software includes the exact description of each of the elements of the drawing. It varies according to the type of element, but the general structure is the following:

- A heading composed of different parameters concerning:
- The type of the element (straight line, broken line, flat shape, circle, etc.);
- The level on which the element is (63 possible levels);
- The size of elements in the file;
- The coordinates of the minimum rectangular including this element (useful for the researches);
- The display symbology (level, colour, thickness and style);
- The properties (new, modified, solid or hole, snappable or not, view dependent, etc.);
- The number of summits.
- The x, y coordinates (and eventually z for a drawing in 3 dimensions) of each summit;
- The links with the database (number of file, number of link in the file).

The principal types of elements are:

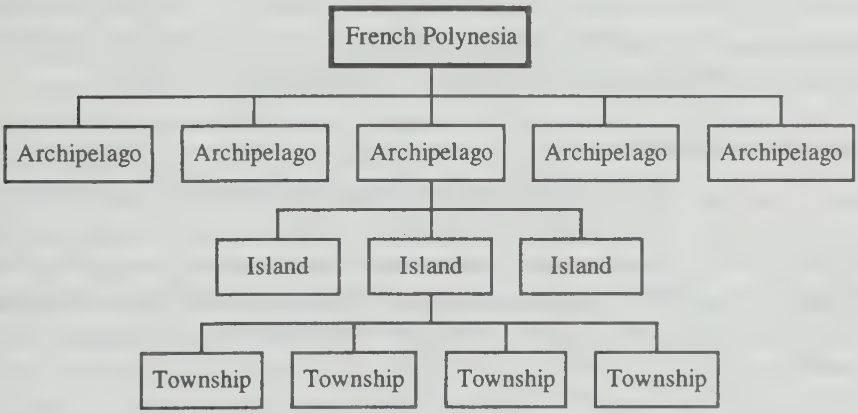
- A straight line: 2 summits;
- A broken line: up to 101 summits;
- A flat shape: polygon of 4 to 101 summits (the last summit having the same coordinates as the first one);
- Circle or ellipse;
- A circular arc;
- A curve: up to 101 summits;
- Text (width and height of variable letters).

3.3.4 *Organization of drawing files*

The research of the best relation and ergonomics of the GIS for the last user has been one of the priority goals, in order to simplify at the utmost the modes of consultation and reduce the length of training of the staff called to use the system.

A method of navigation of the hypermap type has been finalized, with which the user moves geographically. With the schematic map of French Polynesia, the operator shows with the mouse the archipelago, the island and at last the township he wants to visualize. The opening of the files corresponding to each of the steps is controlled by programme, according to a standard code that the user need not memorize. The file of data "ARCHIPEL DBF" contains all the hierarchic organization of the drawing files, the archipelago is above the island, which itself is located hierarchically above the township. This placing allows to "fly over" Polynesia in an arborescent way (cf. Table 1).

Table 1. Hierarchic organization chart of the drawing files



3.3.5 *Organization of the data*

All the data files have a dbase III/IV format. Microstation and its more sophisticated version MGE (work stations, big systems) also accept the Informix and Oracle bases.

The master file contains a recording by data file, describing;

- The name of the data file;
- The name of the principal index (the index key is the number of link MSLINK);
- The name of the format file (for the forms and an screen display);
- The name and the key of two additional index files (to accelerate the researches).

The opening of the master file entails that of the data files and the associated index files.

3.3.6 *Choice of the graphic representation of the digitized elements*

In order to avoid the printing problems met by the SPT, and to simplify the procedures of digitization and handling of the graphic entities, the elements of the curve type have not been used. The shape of the curves are extrapolated on several summits, Microstation creates two invisible points before the beginning and after the end of the curve really digitized, which sets several problems to link perfectly two adjoining curves (identification problems of the link points). Only the elements of the straight line or broken line have been used, even to represent the curves such as the roundabouts in the housing estates, the obligation in those cases is to increase the points.

The buildings have a flat shape (polygon).

The limits of the plots have been digitized in straight and broken lines and not under a polygon shape, for the following reasons:

- Quickness of the digitization: each limit is entered only once, instead of two during the polygon digitization of a limit common to two plots (see picture 1);
- Simplicity and precision: the exact superposing of two continous polygons is very difficult to obtain when there are several summits (case of plots located on side of a mountainous ridge, or drives of housing estate that has a roundabout);
- There is no risk of gaps or several data capture of a plot;
- Simplified collection of sections between themselves.

The compensation of the advantages brought by this method of digitalization is found in the obligation of reconstituting the polygons of plots from contiguous segments because the calculation of a surface can only be done on a polygon. Besides, one must be careful to the meeting point of linear segments, in order to guarantee a perfect close of the polygons (see picture 2). Specific procedures have been created, especially the one that consists of finding automatically the outline of a plot, to calculate its surface and to compare this one with the registered surface at the Service du Cadastre.

3.3.7 Programming languages

The Intergraph company has achieved an open software, allowing the user to bring improvements that are proper to his activity. They are represented under the form of macro-orders, or UCM Language, or under the form of MDL programmes (Microstation Development Language) of an architecture similar to C. Besides, a normal DOS implementation can be launched from Microstation, and its achievement happens on the second graphic screen. This kind of implementations, manage, in a general way, the works on the database.

The MDL language is hard, and difficult to be approached without special training, the procedures of GIS FENUA have be written on UCM when it was necessary to act on the elements of the drawing, and in Dbase or Clipper (clone of dbase) when the works relied on the databases. Because some complex actions cannot be done in UCM, it was necessary to copy again the important parameters of the drawing elements in the files of Dbase format with a UCM, then handle them with external applications.

3.3.8 Rhythm of work

During the making of the plans, we have calculated that two days were the necessary time for the digitization of a cadastral section, and to the link of each plot to the database, considering the method of digitization traditionally used, that is to say under the polygonal form.

But thanks to the method described in section 2.3.5, the time previously assessed has been divided into four, which allows the achievement of complete digitization of a cadastral section in half a day. The rate of 150 plots per day has been obtained for the township of Papara, first township to be digitalized, and a rate of 200 plots/days could have been normally maintained during the twelve necessary days for the complete cover of the township of Paea.

Now, 9,000 plots and as many buildings are integrated into the geographic database. This experience can now be extended to other townships. Besides, the town planning or Papara has also been digitized, and all the contour lines 10 to 150 m, and only the master contour lines of 200, 250 and 300 m on the whole part of Tahiti covered by the maps at the 1/5,000 of the Service de l'Urbanisme.

3.3.9 Quality of the digitization

The exactness of the wedging, the care brought to the digitization and the procedures of control written for the occasion have allowed to guarantee a precision equivalent to the original documents, and sometimes brings to the fore the discrepancies or misconception of these documents.

4.0 Contribution of GIS FENUA

The technical sophisticated methods provided by the GIS within the service are considerable:

- A greater master in the elaboration of the development plans or in the creation of equipment, plans, thanks to a better knowledge of the land;
- A support to the directions of the building permit and information file of development;
- The performance of a research programme applied to the study of the shore line of the Leeward Island for the attendance of a Diplome d'Etudes Approfondies at the French University of the Pacific by Mr Nicolas Marquet in June 1994.

First of all, the GIS has allowed to check up very quickly the state of the land during the development plans in Punaauia and to organize them, for example by accelarating the master of the land hold. During the recent modification of the town planning in the township of Papara, the plots indicated by the citizens or by the township to be corrected as to the zoning were spotted and printed nearly immediately. The answer time of the administration was reduced considerably.

The second advantage that can be drawn from the GIS is great simplification of the instruction of the development information files, because it allows us to know quickly in which urban zone is a plot, and consequently what are the administrative constraints that are linked to it. At the beginning it was necessary to consult several documents at different scales (Cadastre at 1/2,000, zoning of the PGA at 1/5,000) and the date of the updating was different for each of them. Often, the plot that was looked for did not exist on the plans because it was made after the duplication date for each of them. There was a problem especially in the limit of zones. Today, the formalities were limited at the enquiry of the database according to a key of research that groups the code of the township, that of the section and number of the plot. The display of the drawing and the information on the plot is immediate. At last, zoom functions allow to have a general view.

The third contribution of the GIS which covers a field in which the administrative services generally have very little experience is that of the applied research. From February to June 1994, the Service de l'Urbanisme hosted a student preparing a DEA of the French University of the Pacific whose subject was the study of the shoreline of the Leeward Islands. His work was to locate on the field, thanks to map documents, the shoreline of each island according to the category it belonged to (white sand beach, mud pond, rocks, concrete low walls, etc.). According to the same principle, he proceeded to the categorization of the coastal strip, included between the shoreline and the contour line of 20 meters of altitude (high vegetation, low vegetation dense settlement, scattered settlement, hostelry).

Once arrived in the Service de l'Urbanisme, all the information that was collected had to be translated into figures and the line of each of the categories totaled separately, then the shoreline united with the coastal strip. The technical method known up to there was to follow on the map the line that one wanted to measure with a curvimeter whose movements were embodied by a needle on a graduated dial. This method is not reliable because the segments to be measured are numerous and very small. Therefore another method of work had to be created. First of all, the student proceeded with the digitization of the maps. Then special procedures had to be written in order to measure all the segments belonging to each category of shoreline, then to each category of coastal strip, and at last totaling them per category and coupling shoreline and coastal strip.

These works ended in the generation of masters that quantified in value and percentages the lines of each category. Table 2 presents the example of the quantification master of categories of the island of Maupiti.

5.0 Limits of GIS FENUA

There are two categories:

- On an organization level;
- Technical.

5.1 Organization problems

The dispersal between different services, and sometimes the non existence of the basic information makes the updating a GIS difficult.

In fact, if the duplication and the mass data capture techniques of the existing graphic information (plans of cadastral sections) are mastered, the data capture of the surveying documents formalizing a division of the plots poses a certain number of problems. The Service du Cadastre is not yet mechanized, the compiling of plots files and the copying out of surfaces has to be made by hand.

The graphic follow-up of the building is not now done by the Service du Cadastre. The buildings are mentioned on the plots uniquely during the operation of a general cadastral work. During the successive divisions of plots, only the new cadastral limits are drawn. Nobody is able to do an inventory of the buildings.

5.2 Technical limits

All the functions of the software specially turned to GIS that run on workstations, have not been able to be implemented on microcomputer. This deficiency is a little frustrating and does not allow the use of some very useful space analysis tools as regards development. The current situation does not allow the availability in real time of information for other services of the Territory, of average municipalities or network agents.

6.0 For a geographic data bank

The services of the Territory, the townships and the network agents have to wait for the creation of a geographic data bank in charge of managing the whole of the geographic information (map, topography, cadastre, network).

The joint elaboration of several township plans within the framework of the town agreement, the beginning of the renovated Cadastre in several townships, the care of a best productivity of the land tax or the municipal taxes, the requirements of reliability and of rapidity of the administrative decisions and the scale economies that it creates show the need for this data bank.

The technical means exist and their cost is now reasonable. Numerous groups are equipped or are being equipped with this means, and our territory cannot be left out of this technological transformation.

Table 2. Quantification master of categories of the island of Maupiti

Coastal strip / Shore line		1 Clift	2 Natural rock	3 White sand b.	4 Black sand b.	5 Mud grass	6 High vege-table	7 Conglo merate	8i Indivi-dual another	8c Collec-tion another	8r Road. another	8q Wharf another	8a Marae	9 Path dredge	Subtotal Coastal strip
F Clift	Long (m)														
	Per cent total														
I Flooded zone	Long (m)														
	Per cent total														
B Low vegetable	Long (m)					15	60		210						285
	Per cent total					0.1	0.5		1.7						2.3
V High vegetable	Long (m)		490	60		605	455						170		1,785
	Per cent total		4.0	0.5		5.0	3.7						1.4		14.6
C Coconut plant	Long (m)		65	640			195								895
	Per cent total		0.5	5.2			1.6								7.4
A Agriculture	Long (m)			235											235
	Per cent total			1.9											1.9
H1 Scattered settlement	Long (m)		75			530	495		300		540			440	2,385
	Per cent total		0.6			4.3	4.1		2.5		4.4			4.1	19.6
H2 Grouped settlement	Long (m)		175	260		930	1,085		1,080		65		30		3,620
	Per cent total		1.4	2.1		7.6	8.9		8.9		0.5		0.3		29.7
H3 Dense settlement	Long (m)								1,360						1,360
	Per cent total								11.2						11.1
P Collection equipment	Long (m)		50			65			160	760		330		260	1,625
	Per cent total		0.4			0.5			1.3	6.2		2.7		2.1	13.3
H Hostels	Long (m)														
	Per cent total														
S Services	Long (m)														
	Per cent total														
Subtotal Shore line	Long (m)		860	1,190		2,145	2,290		3,105	760	605	330	205	700	12,185
	Per cent total		7.0	9.7		17.6	18.8		25.5	6.2	4.9	2.7	1.7	5.8	100

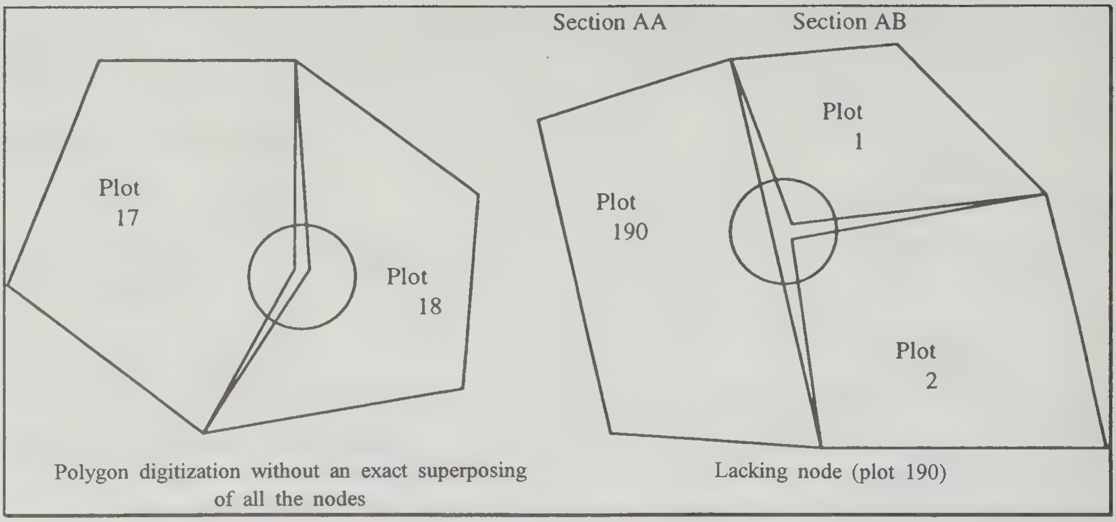


Figure 1. Drawbacks of the polygon digitization. The polygons do not superpose perfectly

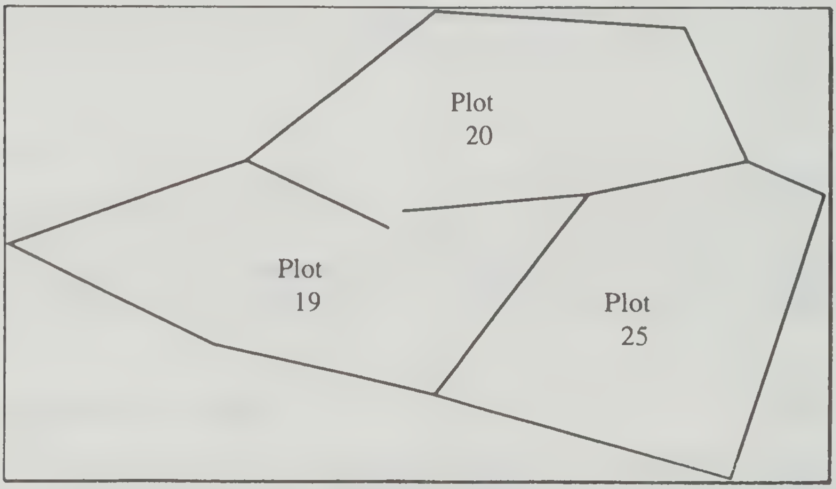


Figure 2. Digitization of plots in segments. This method implies a perfect junction of the segments at the ends

GIS DEVELOPMENT IN GUAM

by

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The Government of Guam has been involved with GIS development in the last several years. We have been developing our parcel base maps with the assistance of the Department of Land Management and private consultants. Because of errors in the survey maps, we have two layers, one is the Survey accurate layer, the other layer is the adjusted layer or planning layer. This layer resolves any problems with gaps and encroachments. It is a picture of how each parcel relates to one another.

We have developed a user group to represent all the agencies of the Government. The user group is responsible for networking government agencies using GIS technology. Data standards and data exchange are let up by the group.

We are presently mapping and capturing various layers including wetland, aquifer recharge areas and general geology as well as infrastructure data.

We will be receiving our digital Cartography next month. This will assist us in our planning efforts. The Government of Guam is also involved with Global Positioning System to re-establish the Geodetic Network and location of infrastructure facilities.

We are starting to develop applications on stop electronic permitting to manage growth development will be undertaken this year. Our user group is involved in networking permitting agencies who are presently using GIS.

GIS IN KIRIBATI

by

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1. MapInfo has been installed and we have received updates under the SOPAC Programme.
2. Training received: two weeks on-the-job training for two nationals on MapInfo.
3. Continuation of inputting data has not been possible owing to the lack of funds to purchase a digitiser.
4. Lands and Survey have a project proposal to acquire GIS but require user friendly software which would be used nationally to make compatibility in data.

On the whole this is a new area, and this workshop has provided Kiribati with an opportunity to acquire information on this technology and ways to apply it in country.

GIS DEVELOPMENT IN THE FEDERATED STATES OF MICRONESIA

by

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The Office of Planning and Statistics in the Federated States of Micronesia is the designated agency for GIS operations for the national Government. OPS will be acquiring *two* GIS systems and will eventually house the "GIS Division" for the national government in the Office of Planning. Assistance for the purchase of hardware and software was provided from the United States Department of the Census and the United States Climate Change Country Studies project. The Census Office will be converting maps created originally with TIGER software.

After consultation with experts from SPREP, Landcare Research and UNEP and also Honolulu private businesses, the decision was made to order PC-Arc/Info software by ESRI rather than Arc/Cad or another type of software from another company. Both OPS (at the Capital in Palikir) and Census Office (in Kolonia) expect to get their systems on-line in February 1995 or by March, at the latest. OPS will hire a full-time GIS operator to digitize maps, and has a consultant coming from Hawaii to do a "gap and needs analysis" to prioritize necessary map and data collection needs of the Federated States of Micronesia. OPS is currently conducting metadata surveys to locate all available maps of the Federated States of Micronesia and the states, find out about their condition, scale and cost of acquisition.

Beginning on March 20th,, OPS will be sponsoring a two week in-country training workshop for beginning PC-Arc/Info. Eight slots for the Federated States of Micronesia participants will be offered. President Bailey Olter asked for a briefing on GIS, and requested that each state governor nominate a candidate plus an alternate to attend this training. The additional four trainees will probably include two candidates from Planning and two from the Census Office. A consultant from Landcare Research in New Zealand will be conducting this training. The first day will be an open-to-the-public seminar; flyers have gone out to all relevant government offices in all four states as well as being displayed on bulletin boards around Pohnpei. This training will be held in the facilities of the Development Institute, a dedicated computer-training private business that works closely with the government. The Disaster Coordinator is also interested in utilizing GIS capability and has indicated to FEMA his need to digitize insurance and hazard map layers.

Pohnpei State

Pohnpei State already has PC-Arc/Info operating and a dedicated full-time GIS data entry person employed in the Office of Budget and Planning. The equipment was acquired for a joint Watershed project funded by the Asian Development Bank (ADB), that is being implemented by the Nature Conservancy field office and Pohnpei State Division of Forestry. The GIS is located in the Department of Budget and Planning in Kolonia. They have a size E color plotter and a full-table size digitizing tablet. Unfortunately, there was no training component for this project and the operator's GIS knowledge is limited.

The Director of Lands attended a GIS workshop at a Coastal Zone conference in January 1992 in Honolulu. He would love to have his staff trained in GIS and get a system, but has not found funding

OPS requested sponsorship from the Australian Embassy (AIDAB) for one indigenous candidate to attend a nine week intensive GIS training in Brisbane. There has been no word on the outcome of this, as yet.

for this. Unfortunately, there is not room to train someone from Lands in the upcoming OPS workshop in March. We are aware of the need to include the Department of Lands.

Pohnpei Utilities Corporation (PUC) and the Municipality of Nett have both said they will send representatives to the March 20th "What is GIS" workshop.

Kosrae State

The newly-elected governor of Kosrae, Moses Mackwelung, is personally interested in GIS and wishes to acquire a system for Kosrae. The Director of Public Works, the Administrator of the Development Review Commission (Kosrae's EPA), and the surveyors in Land Management who are doing land-parcel mapping in AutoCAD 12 all have requested GIS training from OPS. We are looking for funding to do an on-island training and have advised the Kosrae State Office of Planning that when they acquire a system, they should think in terms of Arc/Info to insure compatibility with the National government.

Chuuk State

The only GIS activity in Chuuk, thus far, is acquisition of Map View at Xavier High School from Sea Grant at the University of Hawaii. Students at Xavier are being trained to use this programme.

The government of Chuuk will send a trainee to Pohnpei to learn more about GIS.

Yap State

Yap Marine Resources, Yap EPA, and Lands have all indicated an interest in GIS. They asked that three candidates come to the Pohnpei training, but there is only room in the class to accommodate one.

The private sector

The manager of FSM Telecomm is so interested in GIS that he has requested information from OPS and is considering sending a candidate to ESRI in Redlands, California to get trained in Arc/Info at the company's expense.

REMOTE SENSING AND GIS IN NEW CALEDONIA

by

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1.0 SMAI and ORSTOM Partnership in RS/GIS

1.1 What is the SMAI (Service des Méthodes Administratives et de l'informatique)

New Caledonia is a French Territory located to the Northeast of Australia, at a 3-hour flight from Sydney. It covers an area 400 km long and 50 km wide, oriented SE-NW, which represents 18,575 km^2. About 180,000 people live there, a melting-pot of Europeans, Asians, Polynesians, and Melanesians.

Since the Matignon Accord in 1988, New Caledonia has been managed by five institutions: the three Provinces (North, South, and Isle Province), the Territory and the State of France. Each of them are responsible for different aspects of the political economic and social life. For example, scientific research belongs to the State, and the environment to the Provinces.

The SMAI is one of the technical departments that assists the Territory. It is the administrative computer centre for many public services in New Caledonia (health, taxes, police, customs etc.). The department is composed also of a "scientific computer part", to which belong remote sensing and GIS. Other activities consist in bringing computer assistance to the Mining Public Service through a database called "GeoStock". The ZoNeCo programme has its marine and submarine data processed as well at the SMAI in order to produce charts on the Caledonian exclusive economic zone (EEZ).

1.1.1 Hardware and software equipment

The scientific computer part of the SMAI is fully equiped to process remote sensing and GIS data:

(a) 4 Sun Sparc Work Stations (SS5 — 2 SS10 — X Terminal);
(b) 2 PC's and 1 MacIntosh;
(c) 1 Laser A3 B and W 600 DPI;
(d) 1 Thermal Transfer 300 DPI — A3 Colour Printer;
(e) 1 Thermal Plotting 400 DPI — A0 B and W Printer;
(f) 16 Gb Disk Storage Capacity;
(g) 150 Mo Tape Streamer and 5 Gb 8 mm Tape Driver.

All the hardware communicate through a network (mixed Ethernet 10 base T and 10 base 2), distributed in a 40 m^2 room.

1.1.2 Software is classified as follows

(a)	RDBMS:	ORACLE
(b)	Plotting Tools:	GKS, UNIRAS, PV-WAVE
(c)	Remote Sensing:	OSIRIS
(d)	Image Tool:	Adobe Photoshop
(e)	GIS:	ArcInfo (?)

1.1.3 Staff

The staff of the scientific computer part is composed of four engineers including the head project manager. Some of them are more specialized in system and network administration, in GIS, or in remote sensing.

1.2 What is the ORSTOM (Institut Français de recherche scientifique pour le développement en coopération)

ORSTOM is the French scientific research centre for development. It provides an important remote sensing structure, the MTT ("Mission Technique Télédétection"), which is represented in New Caledonia by the Caledonian LATICAL Image Processing Laboratory.

The LATICAL is connected to ten other ORSTOM remote sensing centres all around the world, among them Montpellier, in France, which is the biggest. Agriculture and land research centres are linked to it (CIRAD, ENGREF, CEMAGREF, INRA).

Remote sensing studies are of varied types: environmental monitoring, impact studies, land-use management, and cartography. ORSTOM has experience in processing SPOT, Landsat, NOAA and ERS1 data.

At the present time, ORSTOM works on research domains such as geographic databases and artificial neural networks for remote sensing applications.

1.3 Their relationships

The SMAI and ORSTOM have organized a partnership since 1992 involving different kinds of activities, among them remote sensing and more recently GIS. All the projects are shared between the two organizations depending on their nature. Productive projects are taken mostly by the SMAI, and ORSTOM carries on more research cases.

OSIRIS is a co-developed software by ORSTOM and the SMAI dedicated to remote sensing. It involved up the four engineers, working on Unix work stations. On adequate screen, it is able to manage 8 bits and 24 bits images containing up to 16 million colours. This tool is used for all the remote sensing projects which need image visualisation, registration, classification, and superimposition on 3D data.

A collection of 40 SPOT images has been acquired since 1986 on the entire Territory and is being used by both organizations for their needs. Another set of SPOT images on the same area has been ordered at the end of 1994, making it possible to do diachronic studies on New Caledonia.

The SMAI and ORSTOM work together for all kinds of customers (public and private) in and out of New Caledonia. The main ones are:

(a) The French marine;
(b) A mining company (the SLN);
(c) The Meteo Bureau;
(d) The French University of Noumea;
(e) Vanuatu and Papua New Guinea.

2.0 Remote sensing and GIS applications

2.1 Lagoon cartography

The French marine has an interest in working with SPOT images. Tropical waters around New Caledonia are clear enough to observe elements in the lagoon. ORSTOM and SMAI help the marine

prepare its charts by registering SPOT images and visualising obstacles to navigation. Images are useful as well to get a quick preview of not well-known regions around barrier reefs.

The French marine has produced many charts based on remote sensing for example: the lagoon of Ouvea, a study presented at the 18th SOPAC meeting in Canberra). Studies on extracting the bathymetry automatically are being run.

2.2 Mining cartography of New Caledonia

New Caledonia has its main economic activity based on the mining industry. The principal mineral extracted is nickel. The SLN (Societe Le Nickel) is the only industry in New Caledonia that transforms ore to nickel, and sells it all around the world. Some mines on the Territory belong to it.

The mining methods in New Caledonia have changed — the environment has become a priority. The SLN had tried to rehabilitate regions that have been damaged by the mining exploitation.

The SLN is interested in having a cartography of all mines in New Caledonia at a medium scale in order to estimate the investment and the kind of rehabilitation that is necessary. The entire Territory is covered by SPOT scenes taken since 1986. A newer coverage is carried on representing 16,500 km^2.

On the base of these data, mines are identified automatically on each image (12 images on the whole), and then integrated in a GIS. Maps can be produced, containing other cartographic and image elements. 3D information will be also taken into account in order to classify the mines found by the slopes: only flat relief will be studied for rehabilitation. The project should last for one year and end in December 1995.

The numeric mines mapping will be available to the public after some months. This layer should be integrated into a global GIS managed by the Territory.

2.3 Eruption of the volcano at Rabaul (Papua New Guinea)

In September 1994, the city of Rabaul in the Province of New Britain was touched by a near volcanic eruption. The region was covered in ash, damaging the habitat and the environment.

The local Papuan authority from the Department of Agriculture contacted ORSTOM mid-October. They were interested by a rapid mapping of land use in the Gazelle Peninsula after the volcanic disaster in order to estimate the crop damages.

The remote sensing department of ORSTOM suggested acquiring two SPOT images, one before and one after the eruption, and processing them in Noumea. A Papuan specialist had to come with local information around Rabaul, helping to interpret the images. Within a week, both SPOT scenes were classified and compared.

It was possible to identify cultures touched by the eruption and to estimate the areas. The Department of Agriculture had information to evaluate financial damages.

3.0 Existing GIS in New Caledonia

3.1 Noumea City Serail Project

The Serail Project is a cartographic, management, and decision-making tool needed by four partners which have different responsibilities in Noumea: Noumea townhall, the post and phone office (OPT), the SCE and EEC companies that are in charge of the water and electricity networks.

First Plans started in 1988 and the legal structure GIE Serail (which means Localized Information Exploitation, Distribution, and Management System) was founded in 1994. The Territory and the South Province were associated with the GIE Serail in 1992. The aim of this structure is to collect geographic information concerning Noumea City from different sources and to redistribute them to the partners.

The repartition of the partners stands as following. The Territory participates in the GIE Serail in supplying Noumea land registry. The South Province provides land-surveyors in order to actualize periodically the data. The City of Noumea lends its hardware (US$ 200,000), and, associated to the other partners (water and electricity networks), finances a new aerial photography cover (US$ 800,000).

Exchange of information is possible through a classified nomenclature of geographical objects (on the whole 9 themes). This nomenclature has been inspired by the EDIGEO European norm, and has been adapted to the specificity of New Caledonia. The information is physically split onto separate places.

Geographic information is divided into three categories: common data (land registry, cartographic elements), exchangeable data (design of networks), and exclusive data (owned by each partners).

The Serail Project is equiped with two work stations including a server and 12 PC's for users. The software AutoCAD is used to prepare data for integration, and the GIS is managed by the French GIS APIC. DXF computer format is used for exchanging information.

Applications to be developed by two persons during 1995:

(a) City patrimony management;
(b) Road exploitation and maintenance;
(c) Urbanism;
(d) Phone, electricity, and water management.

3.2 Customary land registry

The Loyalty Island Province is composed of three main islands named Mare, Lifou, and Ouvea which cover 1,980 km^2 and are separated into districts. The Province has special status from other Provinces as it is an integral autochtonus reserve, where the majority of Melanesians live. This means that the civil laws of New Caledonia do not apply to land property. All the lands belong to the tribes and they are not cessible without their agreement. Customary authorities are responsible for the land property management among private needs.

As reserves are a collective and inalienable entity, no real guaranties can be associated to the lands, even if they are represented by one person or by one tribe. No credits are allowed by the banking system. Consequently, investments are limited and the whole economic life is restrained.

In 1987 and in 1992, at two Loyalty Island Development Colloquies, it was decided to change the customary land properties which were transmitted from generation to generation via oral traditions. It was clear that such a method resulted in wrong information being divulged and was the cause of customary conflicts in the Province. Land property had to be written and conserved for the benefit of future generations.

The customary land inventory was made by district and by tribes under the supervision of their customary big chiefs. Province departments proposed technical, human and financial means to achieve this job. Initially, in 1990, US$ 300,000 were provided for two years, then US$ 66,000 provided annually for five years.

The Topographic Department employs two engineers, and is equipped with one work station connected to A0 digitizer, A3 colour printer, and A0 printer. Software is composed of AutoCad and Automap on PC, Corel Draw and GIS APIC.

In addition to customary land properties management, the GIS aims to collect information such as cartography (scale 1:50,000 and 1:2,000) and triangulation points for a geoid model.

3.3 ZONECO SGVL

EEZ survey by SGVL of New Caledonia Territory.

3.4 Presentation of the ZoNeCo programme

The surface of the Economic Zone around New Caledonia is roughly 1,400,000 km^2. The evaluation of marines resources in the zone is an important issue for the Territory.

In order to prepare a reliable evaluation of marines resources in the Economic Zone of New Caledonia, the Territory decided in 1991 in association with the French State, the Provinces of the Territory, Ifremer, Orstom and Ufp to issue a programme called ZoNeCo. The new research vessel "L'ATALANTE" and improvement in technologies (large scale multi-beam sonar, Acoustic Doppler Currentmeter Profiler, ...) were made possible within reasonable delay and cost to reach the goals of the programme.

The programme integrates two types of activities:

(a) "Operations" constiting of data collecting and processing;
(b) "Data management and information", focusing on putting the available data to practical use.

The programme is divided in three phases:

(a) The "strategic phase" plans to survey and map the seafloor in the areas of interest. The cruises of these operations will collect at least the following information:

- Bathymetry using multi-beam sonar;
- Acoustic imagery provided by sonars;
- Geophysic measures (gravimetry, magnetism, ...).

(b) The "tactical phase" consists of identification of resources on specific sites located during the strategic phase. These studies focused on two kinds of resources:

- Mineral resources;
- Biological resources.

(c) The "target study phase" will quantify the economic value of resources identified during the two other phases. This part of the programme can be optional if private companies are ready to complete the study up the exploitation phase.

3.5 Data management

The data management structure of the programme (called SGVL) settled in the "Departement d'Informatique Scientifique" (Scientific Data Processing Department) in the "Service des Methodes Administratives et de l'Informatique" (Service for Administrative Methods and Data Processing). This office has two main goals:

(a) Management: To collect and store the data of the programme. The "data of the programme" are:

- Data collected during the operations of the programme, like the cruises driven by R/V "L'ATALANTE";
- Data collected before the beginning of the programme, but concerning the New Caledonian EEZ.

The SGVL has to deal with the great diversity of the data: they include morpho-bathymetry, geophysic, physical and biological oceanography, fisheries.

(b) To define and work out the ZoNeCo products generated by the programme. These products can be maps or other documents wanted by end-users. A map can represent one theme or be a correlation between several measures.

The potential end-users are:

1. Enterprises such as commercial fishing, mining companies etc., which are potentially interested in the discovery of new resources;

2. Marine scientists whose research activities aim to increase the overall knowledge of New Caledonia's oceanic region.

3.6 Softwares developed

To achieve the two goals of management and planning of products, the SGVL chose two main software: ORACLE RDBMS and GIS Arc/Info.

- The use of a GIS is justified for the following reasons:
  - Creation of a numeric thematic maps (called covers) library covering the entire EEZ, concerning every discipline of the programme;
  - Analysis of the data stored in each theme;
  - Correlations between covers.
- The database is justified for two main reasons:
  - A powerful tool to manage the data stored by the SGVL;
  - The GIS Arc/Info accept related information of covers stored in an external database.

3.6.1 GANIMEDE

GANIMEDE: Management of external media without writing. External media can be 8 mm and 1/4" magnetic tapes, magneto-optical disk.

This is a tool to store data of the SGVL and to keep information on them. GANIMEDE is based on ORACLE RDBMS.

3.6.2 SIRIUS

This tool uses the functionalities of a GIS plus a RDBMS to consult the entire set of archivated data. The goal is to select data considered interesting for a specific study using several criteria, in a graphical environment.

The cruises and other data collected are drawn according to the working measures of the vessel (multi-beam sonar, gravimeter, ...). Local measures (surface sea temperature, celerity log, ...) can be added. The selection is made according to the themes of interest and a geographic box. The result of this selection is to know the available information on a specific zone and which files to extract to go through the analysis phase.

3.6.3 VEGA

This tool is based on the same GIS as SIRIUS and offers the following main functions:

1. To analyse the data selected by SIRIUS and combine several themes if necessary;

2. To build a map library on the EEZ, edit them and elaborate products from the data of interest. These products will be distributed as paper or numeric documents.

The analysis phase begins by some pre-processing using a specific software. These processing softwares read the data from their original format, allow some base processing and can generate easy to use output format (generally ASCII files).

VEGA accepts input data in a very simple ASCII format and generates a first cover. The first task is to append these data to the map library. The cover needs to go through some process to be coherent with the data already stored. The cover can be printed as a map or output as ASCII file to end-users. The second function is to analyse data, for specifics studies. This task can be illustrated by producing a slope cover from the original data, or find the shorter path according to the relief, or to correlate bathymetry and tuna presence probability. This very rich environment can help scientists working with the programme to validate a hypothesis or test models.

4.0 Projects

4.1 A GIS for the New Caledonia Territory

The New Caledonia Territory is aiming to build a GIS which would hold geographic reference data. Such a database will be accessible to the public and the information will be reused for private needs. A similar initiative already exists in France and is being carried out by the IGN (National Geographical Institut) which is in charge of the whole cartography for France.

At this stage, the Territory has asked its different technical departments to evaluate their needs in GIS. From now on, specific types of data that will contribute to GIS have been identified: cartographic information, land registry, and the relief will constitute the first foundation layers of the GIS. Only very liable data exists in a numeric form: most of it will have to be "computerized" before integration in the database.

The Territory GIS, in fact, will be physically distributed among each department responsible for its own data. Information will be exchanged. At this time, five departments are involved in this network: the Land Registry Department, the Cartographic Service, the Forestry and Agriculture Department, the Mining Service and the SMAI. The SMAI is responsible for the coordination of the project and will help establish the different GIS for the Territory.

4.2 NOAA reception station in New Caledonia

New Caledonia is damaged by drought and suffers occasionally from bush fires. It is more and more necessary to have a tool that allows an analysis of these problems. Spot images cannot offer sufficient repeatedly states of the environment and are of high cost.

The SMAI and ORSTOM intend to widen their cooperation in a new remote sensing domain: besides an existing NOAA station dedicated to meteorological phenomenons managed by the Meteo Bureau, ORSTOM should be equipped in 1995 with of a new NOAA AVHRR reception station by the SMAI for scientific uses. ORSTOM will be in charge of managing the station because of its experience in this matter: the French islands of la Reunion in the Indian Ocean and la Guyanne in South America are equipped with a NOAA station by ORSTOM. The goal is to build an inter-tropical belt with such reception stations.

NOAA data, besides meteorological uses, have land and ocean applications. On land such data may help in following vegetation and forest degradations (by human or natural acts) and may carry out geological studies (lineaments, volcanic activity). From the ocean, NOAA data can contribute to climate analysis, to the study of the physical and chemical processes of water, or to surface current mapping.

This SMAI/ORSTOM NOAA station will be able to process information taken from countries around New Caledonia from Papua New Guinea to New Zealand, and from eastern Australia to Fiji.

4.3 SPOT images on the South Pacific region

Besides the common ORSTOM/Territory SPOT images collection, ORSTOM has its own set of SPOT scenes used by its scientists. Some of them were taken out of New Caledonia.

ORSTOM decided to build a library of SPOT scenes on the South Pacific out of New Caledonia: 50 SPOT images have been ordered at the beginning of 1995 in this region. The biggest collection of satellite images in the region will be available in the following months to carry out studies.

5.0 Regional cooperation

The Territory of New Caledonia wishes to develop regional cooperation. Remote sensing and GIS have proved efficient mostly in Europe and in North America. The South Pacific region should not miss the opportunity of developing such tools.

5.1 Remote sensing

New Caledonia, through ORSTOM and the SMAI, has more than five years experience in remote sensing. Their partnership, based on research and operational services, is a strong base to establish regional cooperation. Different project have already integrated these new relations (Vanuatu, Papua New Guinea).

Possible types of cooperation in remote sensing are:

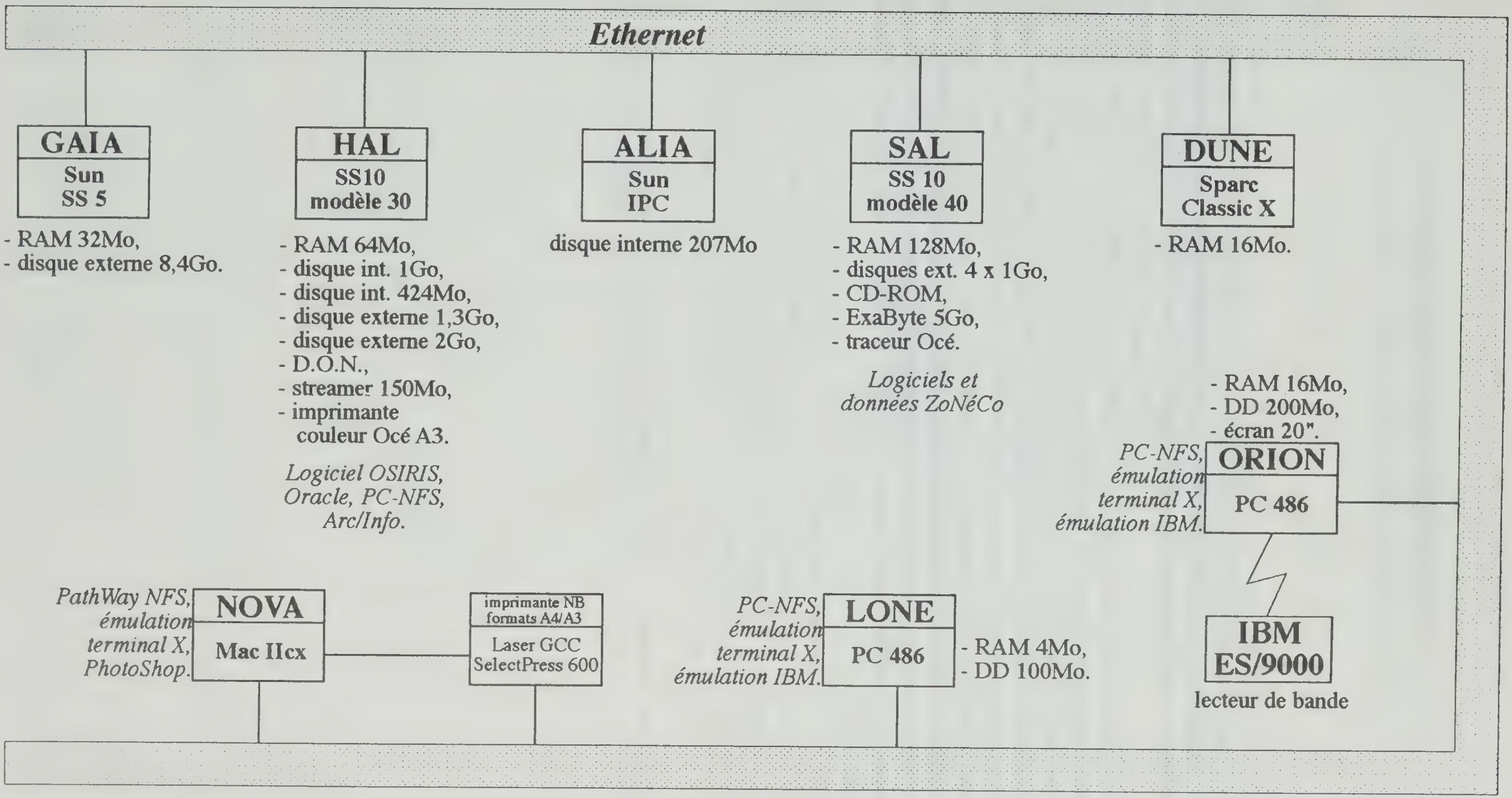
(a) Punctual study cases;
(b) Exchange of information on different themes;
(c) Training courses.

5.2 GIS

GIS has appeared more recently in New Caledonia. Two projects were started more than one year ago: Noumea City GIS and the Customary Land Registry for the Loyalty Islands. Cooperation with similar projects in other countries would be of tremendous help.

The Territory is just starting to use GIS. Information may be exchanged with other organizations dealing with GIS.

SMAI – Département Informatique Scientifique



RS/GIS ACTIVITIES IN NIUE

by

Hubert M. Kalauni,
Lands and Survey, Niue

The remote sensing activities in Niue are new and unfamiliar to all government organisations, but they will be of value once better information becomes available to would-be users. Niue so far has no involvement with this technology but is hoping to use this powerful tool in the near future.

There is no urgent and obvious need right now for Niue to be engaged with remote sensing with the exception of forestry and maritime management.

In regards to GIS, we have the “MAPINFO” software. However, without proper training and mostly hands-on experience, we are not fully utilizing this powerful tool. Since its installation we have concentrated mostly on land ownership and related activities as well as pore sites (water) and soil types. We are looking at the following areas to be included within the system — forestry, land available for leases, conservation areas and public utilities. Disaster programme and environmental issues are important as well but then again basic training is required to identify what information is required, purpose, output and users.

THE PALAU INTEGRATED LAND INFORMATION (LIS) AND GEOGRAPHIC INFORMATION SYSTEM (GIS)

by

Fritz Koshiba,
Bureau of Lands and Surveys, Palau

Although the Integrated LIS/GIS development is still at the technical and organisational consideration stage, two companies, SAGRIC International (Australian firm) and Geo Strategy Inc. (Japanese firm) have submitted their proposals to the Government of Palau.

This project, Integrated (LIS/GIS) will play an important role in strengthening the environmental management regulatory framework. Therefore, any assistance in terms of finances, expert analysis etc. from your respective countries and regional international organisations to properly set up the system would be appreciated.

Basically, the concept of the Integrated LIS/GIS includes land utilisation control, land development control, environmental development control, facility operations control and prevention of disasters/ security control.

The ongoing project, the national master development plan being put together by SAGRIC International, is geared towards economic development prospects in Palau, mainly in tourism, fisheries and agriculture. This clearly justifies the need for governing bodies, departments and agencies of local jurisdictions to utilise and depend upon these systems to provide basic land information, attribute and geographic data to support the decision-making process.

At the present, the emphasis is on developing the Integrated LIS/GIS. However, the application of remote sensing technology will also be developed in the near future.

THE NEED FOR REMOTE SENSING IN THE SOLOMON ISLANDS

by

Renell Zauma Magu,
Ministry of Energy, Water
and Mineral Resources, Solomon Islands

1.0 Definition of remote sensing from the glossary of geology

The collection of information about an object by a recording device that is not in physical contact with it. The term is usually restricted to methods that record reflected or radiated electromagnetic energy, rather than methods that involve significant penetration into the Earth. The technique employs such method devices as the camera, infrared detectors, microwave frequency receivers, and radar systems.

2.0 The need for remote sensing/GIS

Geological work is one of the numerous areas in which remote sensing is useful. Remote sensing is useful for geological appraisal as a first stage approach to geological mapping. With regards to geological mapping, although the islands in the Solomons are small they are inaccessible owing to their rugged terrain and thick rain forest cover. Images from remote sensing have helped and will continue to help to work out the geology and the structures of the islands.

Remote sensing images can also be used for the whole country's mineral reconnaissance work and would also help in the tectonic study of the whole Solomon Islands.

3.0 The required and available level of support in personnel and training

To date, the Solomon Islands have no personnel or specialists in remote sensing/GIS nor do we have the support in personnel and training; not even for detailed aerial photo interpretation, (though we do have aerial photos and a stereoscope).

We are looking into the possibility of employing a female geologist who has an MSc in remote sensing to train staff once a week in remote sensing and report writing. Also we are attempting to organise a three-week course in remote sensing to be held in Honiara sometime in 1995. We hope that the British overseas development assistance from the United Kingdom of Great Britain and Northern Ireland will sponsor this course and the training personnel will be from the British Geological Survey. We have informed Dr R. Howarth our regional contact person with SOPAC, of the idea and he is very interested in sending participants from other Pacific countries. This will be dependent on funding, any United Nations support for this would be most welcome.

4.0 Technical needs

We need every support: hardware, software, data and trained personnel. Technicians should be trained in such areas and there should be an opportunity for funding an MSc candidate in remote sensing for the region.

5.0 Opportunities for regional cooperation

We have the will for regional cooperation. It could be coordinated by SOPAC or SPREP and the facilities could be centralised in one place. We should aim to have in-country geologists trained in remote sensing who can rely on a centralised regional advisor for advice and further training.

RS/GIS ACTIVITIES IN TUVALU

by

Faatasi Malologa,
Ministry of Lands, Survey
and Natural Resources, Tuvalu

Tuvalu is a group of islands stretching north-south between Fiji and Suva. It has 26 square kilometres of land with an increasing population now exceeding 10,000.

RS and GIS in Tuvalu is very limited or does not exist at all.

However, Tuvalu has received assistance from various regional agencies, such as SOPAC and SPREP, regarding a proposal to set up GIS in the country.

An example of this support was the implementation of SOPAC Computer Unit funded by the European Union (EU). The unit was set up with the intention of creating a GIS centre in the country. Although the system was successfully implemented with reliable software for GIS such as Auto CAD and MAP INFO it would have been better if a digitiser had been included. Another major setback regarding this unit was its installation in a different department, PWD, where hardly anyone could use it. Despite all this SOPAC has greatly assisted Tuvalu by providing fellowship training in digital mapping and GIS.

Tuvalu has very limited maps, these include topographic maps provided by the United Kingdom. These vary in scale from 1:12,500 to 1:50,000 and need major updating. Cadastral maps of the country are also available at scales of 1:2,000. However, about 10 per cent of the country remain to be survey. Other maps available include physical outlines of government leased and acquired land. Bathymetric maps of a few islands were provided by SOPAC, including satellite imagery of the Southern Tuvalu exclusive economic zone.

Tuvalu has an alarming increase in population compared with its limited land area. The capital city. Funafuti, has an increasing rate of development with very limited planning. The Government has recently signed an MOU with the Asian Development Bank (ADB) to carry out consultancy on urban planning. This would commence in August 1995.

As a country involved in various regional and international agencies, I feel that it would be advisable to have our needs properly identified and provided with the appropriate support.

Tuvalu has been part of this informative meeting in the past, however it is unfortunate to learn that we cannot apply this know-how to solve our problems at home.

We appreciate the ongoing support of ESCAP and other agencies in providing assistance to our country. However, we recommend country visits by supporting agencies in the future so that our needs can be identified and provided with the relevant support.

RS/GIS ACTIVITIES IN VANUATU

by

Martin Sokomanu,
Department of Lands and Survey, Vanuatu

Before Vanuatu became independent on 30 July 1980, there were many areas of land which were owned by the British, French and Condominium Governments. This land was called "State Land". At independence all state land became public land and now belongs to the Government where as the rest of the land which is not public land remains customary land.

The ni-Vanuatu concept of Land ownership is based heavily on the belief that the land belongs not to the State but to its customary owners, descendants for the original people who first settled the land. Thus, the current customary owners hold and keep that land in trust for themselves and their descendants.

In the Department of Lands and Surveys which is responsible for surveying and mapping of the whole country, we at present do not have a geographic information system but we do have a Land Information System which is now used by the Department of Lands, Land Records and Lands and Surveys.

Our Evaluation Section where the L.I.S. network is based is responsible for collecting Land Registration Information and Land Lease Information from the Departments of Lands and Land Records.

The L.I.S. has been in the Lands and Surveys for about nine years, but in the past two years new systems have been introduced into the department and are now being used by both the surveyors and drafters. The latest arrival is the Micro Station and this system is now set up and a course is now under way for the cartographers and photogrammetrists on its applications and functions.

VANRIS is another system which is used and looked after by the Department for other users from other government departments.

Vanuatu Resource Information System was designed to provide an operational planning tool to assist land-use planners and resource agencies in the management of the country's natural resources. VANRIS is a large and comprehensive inventory of the nation's natural resource land use and population distribution.

It covers the whole country and can be used for development and conservation planning in both customary and market oriented land use situations. This system can be applied at national, regional, island and village levels of land-use planning.

VANRIS was developed during a project to carry out a national forest and national resource inventory of Vanuatu. The project was carried out by the Commonwealth Scientific and Industrial Research Organisation and the Queensland Forest Service.

VANRIS is installed on computers in all the major government agencies concerned with natural resources planning and management in Vanuatu such as Forests, Agriculture, Land Surveys, Environment, Local Government and the National Planning and Statistical Office.

VANRIS is made up of a database management system (FOXPRO 2) and a desk top mapping facility (MAPINFO). This system has benefited both the Department and the Government in land-use planning especially in areas of future development. With the help of VANRIS, officers from Forestry and Agriculture Departments are now able to locate and plan target areas for farmers throughout the islands. Forestry and agricultural development are independent in Vanuatu, particularly at the village level.

With the latest systems and techniques in modern mapping and surveying the Department of Lands and Survey will be able to build a computer based national geographic information system.

This system will be used for future mapping and map revision, assessment of national resources and the construction of national resource inventory, and planning for sustainable development in Vanuatu.

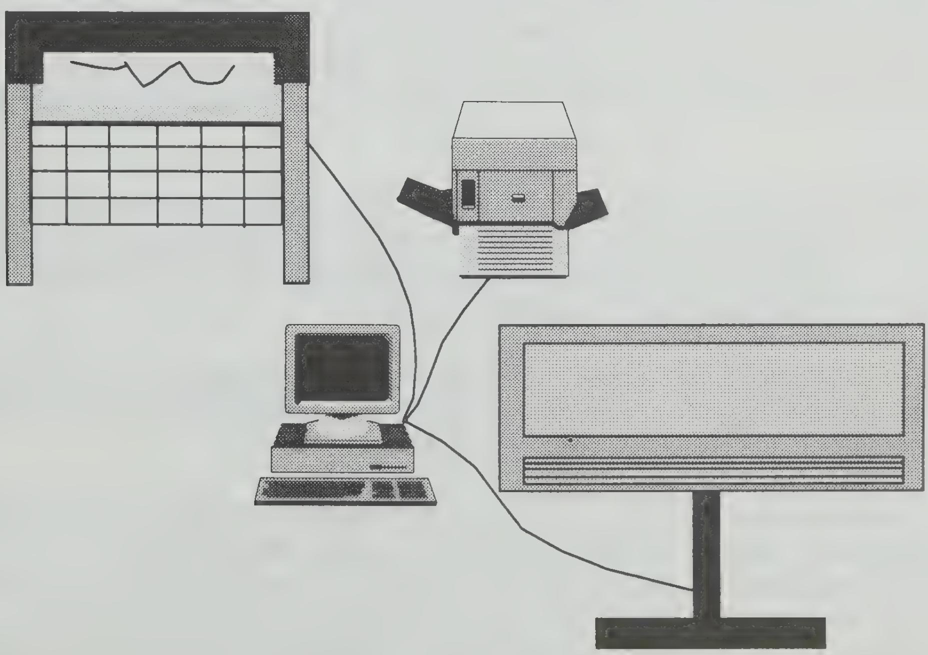
The Vanuatu Department of Land Survey has currently started a digital mapping system, keeping the country in line with world leaders in the GIS mapping field. Vanuatu is capturing all its topographic data into GIS using DIGEST (Digital Geographic Exchange Standard).

The GIS mapping system is operating on a 486 PC using the Intergraph MGE (Modular GIS Environment) software products, running on Windows NT operating system with a Microsoft SQL Server database. MGE is a computerised database management system used for capturing, storing, retrieving, analysing and displaying spatial data. The system is configured with a tape drive, CD, laser printer, A0 digitising table and a HP 650c deskjet plotter.

The geographic database is a collection of geographic information stored as graphic and non graphic data on the computer system. The initial source for this data is the 1:50,000 data plotted on Wild B8 machines and either digitised or scanned into the system. The complete topographic digital coverage of Vanuatu is expected to be completed by the end of 1996.

The current system provides a complete input system with future additions of analysis tools, modelling tools and complete mapping output capabilities to be added at the end of 1995.

The GIS is capable of many products other than topographic maps and this functionality can be added at a later stage of the project.



STATUS REPORT OF THE FORUM FISHERIES AGENCY (FFA)

FFA is regional organization with sixteen member countries. The emphasis is on assisting member countries manage their fishery resources in a way that ensures the sustainable development of fishing resources coupled with optimum economic returns.

FFA is a member of the South Pacific Organizations Coordinating Committee (SPOCC) and works closely with other regional bodies. In terms of activities that relate to GIS development, FFA has entered in to several memorandums of understanding (MOUs) with other organizations. We have an MOU with the South Pacific Commission (SPC) which includes the exchange of data relating to fish stocks and catches in the region, particularly the tuna fishery. Another is with SOPAC with the focus being mapping and legal services; another is with the other SPOCC members with the focus being on GIS and remote sensing.

Our approach is to provide services to member countrues which assist them to better manage their fisheries resources. In terms of computer facilities, FFA has provided hardware, software, data, training and support to each fisheries department or ministry of our Pacific island member countries.

In doing this we have standardised on MS Windows with a similar package of applications to those provided by SOPAC for their primary points of contact within their member countries; this includes MapInfo as the basic mapping/GIS tools.

FFA has produced an application using Ms Access which we have called Corporate Data Resource (CDR). This application links corporate data resources (e.g. vessel, catch, marine product, country etc.) with systems data (e.g. entity, attribute, process, programme, database etc.) and allows for spatial analysis of the data using MapInfo. CDR will be further developed in 1995 to include violations and prosecutions; people and organizations; marine product pricing; and, integration of the SPC logsheet data into and executive information system.

FFA is also in the process of establishing a vessel monitoring system (VMS) that will enhance the ability of member countries monitor foreign fishing vessel activity within the region and their respective exclusive economic zones (EEZs). This system will also facilitate the more efficient use of surveillance resources, which in turn will assist enforcement oprations with in the region. In time it will provide real-time data of fishing activities and will have the facilities to down load information to the fishing vessel using the system.

As part of our vessel monitoring activities, FFA already has regional communication capabilities that are independent of other regional carriers. We have established this capability due to the inability of the regional carriers to provide a reliable and efficient data transfer facility. This means that we are already in a position to facilitate data transfer around the region.

While we make limited use of remotely sensed data (mainly in the form of aerial photography for the Maritime Boundary project), we do have a use for GIS applications and maintain databases that are capable of providing a significant range of information.

One of the data sets that we are developing and will maintain, is the geographic definition of all offshore jurisdictional limits for each of our member countries. This would be one of the fundamental frameworks for any regional GIS. The entry into force on 16 November 1994 of the United Nations Convention on Law of the Sea (UNCLOS) means that member countries who are parties to the Convention not only have particular rights, but also have certain obligations. This obligations include providing

the United Nations Secretary-General with either large scale charts of their maritime jurisdictional limits, or lists of geographic coordinates. As mentioned above, once these are determined they would become a fundamental element of a regional GIS.

FFA has realised the need to place the data that we acquire and analyse in geographic sptial setting, and we realise that we only have limited resources to do this. Therefore, we see the MOU, mentioned above for the SPOCC members, as setting the framework for the sharing and pooling of resources. Also, it should held reduce the tendency for duplication of effort that regional organizations are sometimes accused of.

We consider that this workshop will be a timely means of focusing countries within the region on the issue of GIS and remote sensing development and the benefits that can flow from them. Also, we look forward to working closely with ESCAP in the use of GIS and remote sensing to enhance the sustainable development and management of the region's resources.

SOUTH PACIFIC APPLIED GEOSCIENCE COMMISSION (SOPAC)

by

Phillip Muller, Director of SOPAC

SOPAC is a regional intergovernmental organization whose mandate is to assist its member countries in managing, in a sustainable way, their non-living resources. This implies collecting, storing and analysing and distributing data and information from offshore, coastal and onshore areas. Offshore data includes geological data: bathymetry, submarine imagery, magnetism, gravity, seismic reflection sub bottom profiler, physical ocenographic data: currents, sea surface temperature, wave data, wind and state of the sea.

The objectives of the coastal programme is the management of the coastal zone, identification of new construction material sources, basic mapping, planning,coastal protection and contribution to integrated coastal zone management. The data required are the same as that for the offshore programme together with sediment nature, nature of bottom, quality of water, currents, tides etc. In the onshore programme SOPAC carries out two main programmes, namely water resources and sanitation, and geological hazards. The data collected are aerial photography, digital elevation models, topography maps, geological maps etc. GIS is used extensively to store, process and distribute the data.

SOPAC is building in country capability to generate maps from digital databased on a 5 components package: we distribute hardware, software, data, training and support. As part of an EU funded programme, SOPAC distributed to its ACP member countries PCs with a bundle of software working inside a Microsoft Windows, including Microsoft Office and mapping software: MapInfo, a vector mapping software and Sunfer a gridding/contouring package.

The data came from several sources. From outside, scientific cruises, satellite images, airborne remotely sensed data, digital maps (Defence Mappimg Agency, British Oceanographic Data Centre, World data banks). SOPAC produced data, such as survey data, aerial photographs. SOPAC has a small and handy camera which can be installed on aircrafts widely found in the region), wave data, digital maps. Data will be distributed to the memger countries on CD-ROM which we can cut at the secretariat.

Training is organised within a fellowship scheme by on-the-job training. Pacific Islanders come to the secretariat with a project and the data to realise it. About 15 fellows came during the past two years for training time between 2 and 5 weeks. To break the isolation of professionals back in their country, SOPAC put together a support scheme in the form of a hotline, assuring a fast answer. All means of communications are used: telephone, fax, electronic mail whenever available. In order to develop cooperation in the region, SOPAC took the initiative to elaborate an agreement within regional organizations in the framework of SPOCC, South Pacific Organizations Coordination Committee. The adoption of a Memorandum of Understanding about Remote Sensing and geographic information system during the Forum meeting in August 1994 in Brisbane is a major breakthrough and will open avenues to the development of the use of these tehniques for the benefit of the Pacific island countries.

APPROPRIATE SYSTEMS FOR REGIONAL GIS APPLICATIONS

by

Leslie Allinson,
South Pacific Applied Geoscience Commission

1.0 What is SOPAC?

1.1 Background

The South Pacific Applied Geo-science Commission (SOPAC) is an independent, intergovernmental, regional organization established by several South Pacific nations in 1972, originally as CCOP/SOPAC. Its Secretariat is located in Suva, Fiji, and has about 40 professional and support staff. All of its sixteen members are developing Pacific island countries except Australia and New Zealand, which do not receive work programme assistance but are major donours.

Member countries are currently Australia, Cook Islands, Federated States of Micronesia, Fiji, Guam, Kiribati, Marshall Islands, New Zealand, Niue, Papua New Guinea, Solomon Islands, Tonga, Tuvalu, Vanuatu, and Samoa. French Polynesia and New Caledonia are associate members.

1.2 The mission statement

To improve the well-being of the peoples of Pacific island member countries through the application of geoscience to the management and sustainable development of their non-living resources.

1.3 Work programme

Through its Secretariat, SOPAC carries out a wide range of geoscience activities in the region. The Secretariat's primary roles are to gather new data to assist member countries to assess their natural resources, and to build national capacities in the geosciences towards self-sufficiency in the long term. Not all of the activities listed below are carried out at any one time, the balance of the work programme depending on member country priorities and on the level of funding available to SOPAC at the time.

1.3.1 Environmental geoscience

- Coastal environment monitoring;
- Coastal processes studies;
- Coastal management advice;
- Coastal protection assessment;
- Geohazard assessment;
- Bathymetric mapping;
- Remote sensing mapping;
- Airphoto surveys;
- Seabed mapping;
- Cruise coordination and data collection;
- Water resources and sanitation.

1.3.2 Mineral and energy resources

- Assessment of coastal, onshore and offshore mineral potential;
- Aggregate assessment and mining strategy;

- Evaluation of hydrocarbon potential;
- Wave energy assessment and promotion;
- Geothermal energy assessment.

1.3.3 Human resources development

- Degree and certificate studies;
- Workshops and seminars;
- On-the-job training;
- HRD advisory assistance.

1.3.4 Technical services

- Regional data centre;
- Remote sensing facilities;
- Information services;
- Field support services.

1.4 Publications

- SOPAC News (4 per year);
- Technical Bulletin (ad hoc);
- SOPAC Projects (2 per year);
- Fiji Users GIS and RS Newsletter (6 per year).

1.5 SOPAC data holdings

- Cruise data — ship tracks;
- Bathymetry;
- Gravity and Magnetics;
- Significant points (e.g. seamounts);
- Aerial Photos;
- Maps;
- Satellite Images;
- EEZ boundaries;
- Minerals;
- Surveys;
- Publications.

2.0 Member country assistance

2.1 Purpose

Provide assistance to member countries through identification of funding to procure appropriate equipment, develop information systems and provide necessary training.

A standard set of applications was provided to the eight ACP member countries of Fiji, Kiribati, Papua New Guinea, Solomon Islands, Tonga, Tuvalu, Vanuatu and Samoa under the EU funded Pacific Marine Resources Programme and the equipment was formally handed over at the commencement of the Resource Assessment Workshop which was held at SOPAC in June 1993. After the workshop, the equipment was sent by air to the recipient country and follow-up visits were undertaken to provide more comprehensive training, development of in-house systems and assistance with future development. Emphasis was placed on the future development of a regional wide network, or wide area network, for the exchange of data and resource sharing.

Software standards have been developed and include the Microsoft Office Professional suite as the common set with MapInfo and Surfer for GIS applications. This standard set provides compatibility with SOPAC and other regional organizations including FFA:

- MS-DOS 6.2;
- Windows for Workgroups 3.11;
- Microsoft Office Professional 4.3;
  - — Word 6.0
  - — Excel 5.0
  - — PowerPoint 4.0
  - — Access 2.0
- MapInfo for Windows 3.0;
- Surfer for Windows 5.0;
- Geographic Calculator;
- Utilities;
  - — Norton
  - — FastLynx
  - — Virtual Tablet Interface.

The hardware includes:

- PC 486/33 240Mb HDD 16Mb RAM;
- 15" monitor 1,204 x 768 resolution;
- CD-ROM (multi-media kit);
- Printer — Laserjet 4M 6Mb RAM — 600 dpi;
- 600 VA UPS and 6 outlet power board.

3.0 MOU on exchange of GIS and RS data

A MOU on data exchange created between the following organizations:

- South Pacific Applied Geoscience Commission (SOPAC);
- South Pacific Commission (SPC);
- South Pacific Forum Fisheries Agency (FFA);
- South Pacific Regional Environment Programme (SPREP);
- University of the South Pacific (USP).

The benefits are:

- Data sharing;
- Data holdings catalogued;
- Cost savings through reduction in duplication of purchase.

4.0 Communications network

Many SOPAC member countries have local area networks and include Fiji, Kiribati, Papua New Guinea, Vanuatu and Samoa and the remainder plan installations in 1995.

There will be regional connectivity (Wide Area Networks) using the Public Switched Telephone Network and the public non-commercial PEACESAT network.

The advantages are access to Internet, low or no cost voice and data sharing and SOPAC plans to install a World Wide Web server to provide a regional GIS and RS catalogue.

SOUTH PACIFIC COMMISSION

by

Tim Adams, Fisheries Resource Adviser

The South Pacific Commission is a regional organization subscribed to, and controlled by the Governments of Australia, American Samoa, the Cook Islands, the Federated States of Micronesia, Fiji, France, French Polynesia, Guam, Kiribati, the Marshall Islands, New Caledonia, New Zealand Niue, Northern Mariana Islands, Papua New Guinea, Palau, Solomon Islands, Tokelau, Tonga, Tuvalu, the United Kingdom, the United States, Vanuatu, Wallis and Futuna, ans Samoa. SPC provides a development and advisory service to the Pacific islands with programmes in several areas, including health, agriculture, youth, women, statistics, and demography. It is SPC's largest programme, the Fisheries Programme, which has the greatest current interest in using remote sensing and spatial information systems in its work. Unlike the South Pacific Regional Environment Programme (SPREP) and the South Pacific Applied Geosciences Commission (SOPAC), SPC is not currently capable of supporting direct RS/GIS assistance to member countries, but is interested in using this technology to enhance existing services in fisheries management to member countries. SPC has signed a Memorandum of Understanding with other South Pacific regional organizations (FFA, SOPAC, SPREP and USP) to facilitate the sharing of remote sensing data and avoidance of duplication of effort, through the South Pacific Organizations Coordinating Committee (SPOCC).

Like the Forum Fisheries Agency, SPC makes considerable use of spatially referenced data in the assessment and monitoring of tuna fisheries, including several types of cartographical interface, although SPC's oceanic fisheries work is more scientific in nature than the FFA's political and economic mandate. It is in the region's marine coastal zones that we feel the greatest geographical information gap remains, and the SPC Coastal Fisheries Programme is making efforts to acquire relevant information in this area. One major initiative is the United Kingdom-funded Integrated Coastal Fisheries Management Project, which will assist member countries over the next three years to prepare and implement management plans for coastal fisheries which are a high priority, mainly because of overfishing of certain specialised resources to supply Asian export markets. The developing Regional Inshore Fisheries Statistical Database will be used as the basis for a broad-scale nearshore marine spatial information system, and it is planned to integrate this with detailed remotely-sensed information in specific country project areas. This system will be used to illustrate and support national inshore fishery management plans and alternatives, particularly for the benefit of decision makers and public education, but will also be a continuous regional resource for the future. Our information system is Pentium PC-based, currently using FoxPro and working towards integration with MapInfo, but other products will be evaluated as needs expand. A regional workshop on Coastal Fisheries Management will be held in June and one of the items on the agenda will be the selection of several country projects to integrate with this activity.

During its evaluation by the Fisheries Programme, it is likely that the use of GIS as a tool for rendering spatially-referenced data into more easily understandable and manageable form will become integrated into other SPC work programmes, particularly Agriculture, Demography and Health.

SOUTH PACIFIC REGIONAL ENVIRONMENT PROGRAMME
PACIFIC ENVIRONMENT AND NATURAL INFORMATION CENTRE

by

Bismarck Crawley

1.0 Introduction

For the past two years, the UNEP Environment Assessment Programme for Asia and the Pacific through SPREP established and maintained the Pacific Environment and Natural Resource Information Centre to service the environment information needs of the member countries of the South Pacific for sustainable planning and environmentally sound decision making.

The establishment of PENRIC was attributed to a network action strategy that was to coordinate countries and institutions in faclitating world decision-making and action towards sustainable development. Given the importance of coodination in facilitating all levels of decision-making, PENRIC, like other chapters, was directed to foster inter-institutional cooperation and coordination with users/donours to minimise duplication and to get people and institutions connected.

The core of PENRIC was to assess existing environment data, identify their status in terms of format availability. As a means of collation, manipulation and dissemination of the data, GIS and remote sensing was incorporated to integrate all layers of data for sustainable planning and development. Given the status of the tool in the region, the focus was also on helping to build and strengthen existing national capabilities for human resources development through training, institution building and provisions for hardware and software where appropriate.

2.0 Aim

To increase the overall awareness and understanding of the environment and the cultural heritage in order to promote positive community attitudes towards environmental activities and decision-making in the region.

3.0 Basis for Action

3.1 United Nations Couference in Environment and Development, Agenda 21, Information for Decision making

To bring together diverse skills and common perceptions on environmental issues across the geographical boundaries involving both regional/subregional institutions and countries in the region;

To underline the importance of an improved availability of information on all aspects of the environment and development in decision-making towards sustainable development which is further supported by the need for periodic assessment of the State of the Environment Database at national, regional and global level.

3.2 The SPREP Action Plan

SPREP was mandated to take the coordinating role in environmental issues for the South Pacific region. The thrust of its Action Plan is determined by the projects within the programme, in collaboration with the National Environment Management Strategies developed for its member countries.

The existence of PENRIC was seen as an area to develop, maintain and centralise database requirements and output of the in house projects.

4.0 Projects areas

1. Climate change and sea-level rise;
2. Population and development;
3. South Pacific biodiversity conservation programme;
4. Environment education;
5. Pollution management;
6. Environment impact assessment;
7. Information and publication.

5.0 Objectives

1. Assess the current state of available data and expertise in the region as well as their requirements;
2. Undertake awareness programmes on the capacity of the GIS tool and its utilization to activate the decision-making process;
3. Establish national environment information management systems, where appropriate, taking into consideration the emerging national environment management strategies within the member countries;
4. Support the South Pacific biodiversity conservation programme and SPREP's Action Plan in regional and national activities;
5. Provide a Pacific framework in the implementation of the Agenda 21 project in close consultation with UNEP Environment Assessment subprogramme, Global Monitoring Systems (GEMS) and the Global Resource Information Database (GRID) in Bangkok;
6. Underline geographic information systems/remote sensing as an action strategy tool for sustainable planning and decision-making in the region through the SPREP work plan;
7. Actively implement the RENRIC network strategy, through capacity-building, environment sensing and catalysing government response.

6.0 International/Regional linkages

1. UNEP Environment Assessment Programme, GEMS, GRID;
2. World Conservation Monitoring Centre, "Reefbase Project";
3. UNEP RENRIC Network;
4. Regional GIS User Group: SPC, FFA, SOPAC, USP;
5. University of the South Pacific.

7.0 Software

1. DOS Version 5.0;
2. PC ARC/INFO Version 3.4D Plus;
3. ERDAS Version 7.5;
4. IDRISI Version 4.1;
5. ACRVIEW.

8.0 Hardware

1. Acer 20MHz '386' upgraded to 486DX CPU;

2. Toshiba Laptop, colour, 486;
3. Digitizer: Calcomp 9,500, A1, 24' x 36', with 16 button cursor;
4. Plotter: Calcomp Pacesetter Model 2,024, A1, pinch roller, 8 pen carousel;
5. Printer: Epson LQ-1,170, 24 pin, wide carriage non colour printer Painget Colour, A4;
6. Tape Drive: Cypher M995, reel to reel tape drive, 2,400/6,250 bps, SCSI i/f.

9.0 Achievements/Involvement

1. GIS Training Facility with USP;
2. Community Deforestation Project for Niue and Samoa;
3. GIS Facility with the Fiji Environment Unit in collaboration with the Australian Marine Science and Technology Limited (AMSAT);
4. GIS Needs Assessment for Solomon Islands, Vanuatu, Tonga and Samoa;
5. GIS Awareness through the NEMS Project for Niue and Kiribati;
6. GIS Awareness through the South Pacific biodiversity conservation programme;
7. GIS Training and Installation for Pohnpei Watershed management Project in collaboration with AMSAT;
8. Evaluation of a national coastal management proposal for GIS utilization for American Samoa;
9. Partially completed macro-database for the South Pacific region;
10. Completion of Volume 1 of the Pacific Regional Environment Directory for experts and institutions in collaboration with landcare research.

10.0 Work plan and expected output for 1994-1995

10.1 Capacity-building

Network
- Improved awareness on the use of GIS/RS tools for sound decision-making;
- Development of ENRIC for Samoa.

Training
- Training at three levels for the proposed ENRIC; policy, professional, technical;
- 2 case study applications.

10.2 Data management

- Completion of the Macro-Database for the South Pacific region;
- Pacific Spatial Information Update;
- Further collaborations with GIS/RS User Group for other GIS Activities in the region.

10.3 Environment assessment

- Development and production of State of Environment Database for the region.

PART FOUR
ANNEXES

ANNEX 1

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ANNEX 2

WELCOME ADDRESS BY BHUWAN DUTT, PERMANENT SECRETARY FOR LANDS, MINERAL RESOURCES AND ENERGY

Eighteen countries in this region were invited to this workshop and I am glad to note that most of them are present here today.

I would like to thank UNDP and ESCAP for the support given to the regional remote sensing programme (RRSP) which started several years ago. This has provided a good foundation which has given an impetus to remote sensing activities in the region. This workshop is a good example of the benefit that flows from the programme.

Fiji has appointed the Permanent Secretary for Lands, Mineral Resources and Energy as the focal point for RRSP activities, and we have gained significantly from various intergovernmental coordinating committees and other meetings that we have attended over the years.

The Ministerial Conference on Space Applications for Development in Asia and the Pacific held in Beijing China in September 1994 saw the declaration and launching of the Regional Space Applications Programme for Development in the ESCAP region. It is pleasing to see that this workshop has been organized as soon as practicable after the Declaration. Thus we can see that an action-oriented plan is what is being pursued so as to achieve maximum benefit.

During this week we are given the task of producing an action plan for the pacific. I am sure we well succeed in doing so in the true pacific way through Dialogue, cooperation and coordination.

Finally I wish to acknowledge the work of the organizing team mobilised to organize this workshop. A lot of hard work has gone into this and I wish to thank the committee members and ESCAP and UNDP for their contribution and support.

ANNEX 3

STATEMENT OF THE ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC (ESCAP)

It gives me great pleasure, on behalf of the ESCAP secretariat, to welcome you all to the Remote Sensing/GIS Workshop for Land and Marine Resources and Environment Management in the Pacific Subregion. This workshop has been organized by ESCAP in close collaboration with the Government of Fiji and with support from the South Pacific Commission , the United Nations Environment Programme, through the South Pacific Regional Environment Programme and the University of South Pacific.

It has always been very exciting for ESCAP to be associated with this high-technology application that is now widely recognized as an essential component for the proper planning and management of the planet's resources. It is a well-known fact that, today, remote sensing and GIS technologies have become necessary and efficient tools for natural resources management and for environmental monitoring problems such as global climate change, desertification/deforestation, and natural hazards such as floods, droughts, earthquakes, landslides, volcanic activity, tropical storms and oceanic abnormalities.

The Regional Remote Sensing Progamme or RRSP, initiated by ESCAP in 1983 with financial support from UNDP, is proud to have contributed in stimulating the interest of the subregion in the technologies through successive promotional efforts. It has done so by organizing, among other activities, various training courses and meetings including workshops and a working group meeting on regional cooperation in applications of remote sensing and GIS technology for the South Pacific in 1991. Between 1988 and 1990, ESCAP initiated a subprogramme for the subregion that was hosted by the Institute of Natural Resources of the University of South Pacific. Within this subprogramme, headed by one of our experts posted they for three years, a subregional network was initiated and a number of activities were undertaken. In the past two years, the subregion was visited by the Regional Advisor on remote sensing/GIS of ESCAP to assess and discuss development requirements with respect to this technology. All these efforts, initiated by ESCAP in close cooperation with South Pacific countries and Pacific regional organizations, have formed an essential component contributing to subregional capability-building.

ESCAP finds it very encouraging to know that several regional organizations in the South Pacific region have used or are currently using remote sensing/GIS to various degrees in the implementation of development projects. The setting up of a regional remote sensing user group consisting of eight regional agencies including the South Pacific Commission, the Forum Fisheries Agency, the South Pacific Regional Environment Programme, the University of South Pacific and the South Pacific Bureau for Applied Geoscience, in an effort to facilitate the sharing of their respective information and databases and the coordination of their activities, is a particularly welcome development in that regard. At the national level considerable progress has been achieved in the field of GIS/remote sensing applications in the subregion over the past 5-10 years.

We are fully aware, however, that despite these efforts, enhanced cooperation has yet to be developed in order to meet the growing development requirements of these countries in this important field of technology application ESCAP firmly believes that, by working closely alongside SPOCC (the South Pacific Organizations Coordinating Committee) and its associated, agencies, important strides will be made towards improving the capabilities of the individual countries in the region in natural resources and environmental management.

This workshop was designed and has been organized to expose senior officials from departments utilizing remote sensing and/or GIS for land and marine resources and environment management to the new techniques. The applications discussed will principally focus on the development and planning of land and marine natural resources, environment management as well as disaster monitoring. The first part of the workshop will be dedicated to the experiences of participants from the region in this field of technology, presentations will be made by the country representatives; lectures will be given by a number of experts; and technical visits will take place to a number of local agencies where live demonstrations will be given of the application of remote sensing/GIS technology to address natural resources and environment management problems.

Another objective of the workshop is to allow the participants to explore the various avenues open to them for improving cooperation and supporting national development needs in the use of this technology in the Pacific islands countries. Indeed, during a working group meeting scheduled to take place here, discussions will be held on technical issues such as data needs, current data analysis methods, system updates and the maintenance of existing equipment; but also on more general issues such as the need for remote sensing and GIS technology in national development, the required versus the available level of support in personnel and training, and, last but not least, opportunities for regional cooperation. The primary aim of this working group is to conceptualize a Pacific subregional action plan for GIS/ remote sensing applications as one of the follow-up actions resulting from the recommendations of the Ministerial Conference on Space Applications for Development in Asia and the Pacific held last September in Beijing.

Before I conclude, let me express our most sincere thanks to the Government of Fiji for hosting this important event, and to the local organizers for their efforts in making all the necessary arrangements for the meeting. I would also like to express our appreciation to the United Nations Development Programme for their continued and generous support to ESCAP in funding remote sensing/GIS activities in the subregion and for their assistance in organizing this event.

ANNEX 4

ADDRESS BY UNDP RESIDENT REPRESENTATIVE

UNDP has been pleased to provide support to the Asian and Pacific countries for the Regional Remote Sensing Programme for over ten years now, with ESCAP as the executing agency throughout. The Regional Remote Sensing Programme was instrumental in establishing a highly developed infrastructure in remote sensing in participating countries. To ensure broader application and use, UNDP is currently providing some US$ 1.5 million to the Asia-Pacific region as a whole for a programme on integrated applications of GIS and remote sensing for sustainable natural resources and environment management. This current programme — of which this workshop is one activity — runs from 1993 to 1997 and is also executed by ESCAP. The programme addresses the issues of a wider application of the data and information obtained through remote sensing and GIS for planners and decision makers.

While it is true that the costs involved are not inconsequential, it seems most appropriate that we come together as a group from the South Pacific to discuss this issue, rather than working on a purely national basis, in isolation.

By coming together as a group, we now have in this room a wealth of experience on GIS/Remote Sensing applications allowing us to really hear first hand the successes and failures of different stages in the implementation of these programmes that are, lets face it, complex and ambitious both in their technology and their policy application.

By meeting as a regional grouping, in addition, the experience here is already to a certain extent "customized" to the local characteristics of the region. I am thinking here, for example, of the important work done by the Fiji Land Information System with customary land issues; which I understand is of interest to many other countries in the region, Australia and New Zealand included.

By coming together as a group, also, a whole new set of options are before us that need not be constrained by national boundaries. Pooling our expertise, our efforts and perhaps in some instances our finances in the GIS/Remote Sensing sector seems in my mind to make a lot of sense in providing us with a more viable and sustainable basis upon which to build new endeavours in this fast changing field.

I see from the programme that the workshop has been designed in a very practical fashion, with a number of working of group meetings including one which will look at how to promote cooperation in GIS/remote sensing applications in the Pacific and even the formulation of a Pacific subregional action plan.

I very much welcome this initiative, wish you well in your deliberations and look forward to seeing some positive and innovative outcomes.

ANNEX 5

ADDRESS BY THE HONOURABLE RATU T.W. VESIKULA, MINISTER FOR LANDS, MINERAL RESOURCES AND ENERGY

I am greatly honoured this morning to inaugurate this Workshop on Geographic Information Systems and Remote Sensing for Lands and Marine Resources and Environment Managements in the Pacific Subregion. I would like to express our most sincere thanks to the Regional Remote Sensing Programme of the United Nations Economic and Social Commission for Asia and the Pacific for organizing this workshop.

All of this, of course, would not have been possible without the dedicated United Nations Development Programme support of the regional remote sensing programme. We wish to place on record our profound appreciation to all these institutions for their continued technical support.

The government of Fiji has recognized the importance of remote sensing and geographic information systems. The establishment of the Fiji Land Information Project, the Soil and Crop Evaluation Project and the Fiji Forestry inventory and Mapping Project are significant reflections of this policy. On behalf of the government of Fiji I would like to thank the governments of New Zealand Australia, Germany and France for the support provided over the years.

The Fiji Land Information Systems Project is a government initiative aimed at addressing a corporate and cooperative approach to the computerisation of a number of manual land-related records, thus gaining the maximum benefit for land administration activities and providing better information for the planning and utilisation of the nation's limited land resources.

Member countries in our region are still in the developing stage. Most are confronted with similar problems such as limited natural resources and a substantial lack of technical expertise. As the populations grow, there is increasing pressure on land and resources. There is a need to exploit new resources to provide decent living standards for the people and to monitor environmental changes resulting from both natural processes and human activities.

There is a growing realisation now that socio-economic development can be sustainable only if resources are exploited in a judicious manner and consideration is taken of the long- and short-term impact of resource exploitation and development activities on the environment. Geographic information systems and remote sensing are versatile and promising tools that can be gainfully employed in conjunction with satellite-based data for optimising resource and environmental management.

Although most countries in Asia have established national remote sensing centres and programmes and are applying the technology in varying degrees, we in the Pacific region have only relatively recently investigated the capability of the technology. Some of the most significant obstacles in our way remain the noticeable shortage of suitably qualified personnel to undertake this task and the lack of any receiving capability for satellite generated data. I understand that this workshop will seriously attempt to address these deficiencies and recommend ways of improving the situation.

We strongly believe that the widespread utility of this technology in the Pacific will follow a sufficiently aggressive human resources development strategy. To this end my ministry has actively supported the establishment of the Geographic Information System Unit at the Regional University of the South

Pacific and I understand plans are afoot to introduce a diploma level programme in the near future. I am hopeful that this programme will receive the support of the regional countries and donour agencies.

During the course of the workshop you will also be exposed to new techniques and discuss the applications of remote sensing and geographic information system technology in natural resource development and planning, environmental management, disaster monitoring such as cyclone warning and damage assessment.

Apart from the theoretical discussions and presentations, you will participate in what I believe to be the most important aspect of this workshop — a working group meeting that will conceptualize a Pacific subregional action plan. Your active participation in this working group will ensure that we will have a coordinated and cooperative Pacific-wide strategy, a blueprint particularly addressing the relevant issues, that will launch us into the year 2000.

In your deliberations during the workshop you will be guided by three important milestones that came out of the Ministerial Conference on Space Applications for Development held in Beijing, China during September.

These include the Beijing Declaration on Space Technology Applications for Environmentally Sound and Sustainable Development in Asia and the Pacific, the Strategy for Regional Cooperation in Space Applications for Sustainable development, and the Action Plan on Space Applications for Sustainable Development in Asia and the Pacific.

These milestones provide guidelines for promoting the regional space applications programme for sustainable development within the framework of greater cooperation and coordination at the national, regional and international levels. I am sure that your discussions this week will sufficiently address these issues.

Pacific and I understand plans are afoot to introduce a diploma level programme in the near future. I am hopeful that this programme will receive the support of the regional countries and donor agencies.

During the course of the workshop you will also be exposed to new techniques and discuss the applications of remote sensing and geographic information system technology in natural resource development and planning, environmental management, disaster monitoring such as cyclone warning and damage assessment.

Apart from the theoretical discussions and presentations you will participate in what I believe to be the most important aspect of this workshop — a working group meeting that will conceptualize a Pacific subregional action plan. Your active participation in the working group will ensure that we will have a coordinated and cooperative Pacific-wide strategy, a blueprint particularly addressing the relevant issues, that will launch us into the year 2000.

Your deliberations during the workshop will be guided by three important milestones that came out of the Ministerial Conference on Space Applications for Development held in Beijing, China during September.

These include the Beijing Declaration on Space Technology Applications for Environmentally Sound and Sustainable Development in Asia and the Pacific, the Strategy for Regional Cooperation in Space Applications for Sustainable development, and the Action Plan on Space Applications for Sustainable Development in Asia and the Pacific.

These milestones provide guidelines for promoting the regional space applications programme for sustainable development within the framework of greater cooperation and coordination at the national, regional and international levels. I am sure that you, the users of this work, will constantly address them.

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